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REPORT OF SURVEY CONDUCTED AT

ITT INDUSTRIES
AEROSPACE/COMMUNICATIONS DIVISION
FORT WAYNE, IN

APRIL 1998

Best Manufacturing Practices

1998 Award Winner

INNOVATIONS IN AMERICAN GOVERNMENT

BEST MANUFACTURING PRACTICES CENTER OF EXCELLENCE
College Park, Maryland
www.bmpcoe.org

Foreword

This report was produced by the Best Manufacturing Practices (BMP) program, a unique industry and government cooperative technology transfer effort that improves the competitiveness of America's industrial base both here and abroad. Our main goal at BMP is to increase the quality, reliability, and maintainability of goods produced by American firms. The primary objective toward this goal is simple: to identify best practices, document them, and then encourage industry and government to share information about them.

The BMP program set out in 1985 to help businesses by identifying, researching, and promoting exceptional manufacturing practices, methods, and procedures in design, test, production, facilities, logistics, and management – all areas which are highlighted in the Department of Defense's 4245.7-M, *Transition from Development to Production* manual. By fostering the sharing of information across industry lines, BMP has become a resource in helping companies identify their weak areas and examine how other companies have improved similar situations. This sharing of ideas allows companies to learn from others' attempts and to avoid costly and time-consuming duplication.

BMP identifies and documents best practices by conducting in-depth, voluntary surveys such as this one at ITT Industries Aerospace/Communications Division, Fort Wayne, Indiana conducted during the week of April 20, 1998. Teams of BMP experts work hand-in-hand on-site with the company to examine existing practices, uncover best practices, and identify areas for even better practices.

The final survey report, which details the findings, is distributed electronically and in hard copy to thousands of representatives from industry, government, and academia throughout the U.S. and Canada – *so the knowledge can be shared.* BMP also distributes this information through several interactive services which include CD-ROMs, BMPnet, and a World Wide Web Home Page located on the Internet at http://www.bmpcoe.org. The actual exchange of detailed data is between companies at their discretion.

ITT gained its world-class reputation by providing reliable, high quality products and services pertaining to Forward Area Battlefield Communications and Space Navigation/Meteorological Systems. The company continues to support this effort through engineering excellence and innovation, and thrives today as a high-technology leader with real-world impact. Among the best examples were ITT's accomplishments in commercial parts process; supplier integrated product development; surface mount device processing database; test time reduction; integrated management plan; and risk management process.

The Best Manufacturing Practices program is committed to strengthening the U.S. industrial base. Survey findings in reports such as this one on ITT Industries Aerospace/Communications Division expand BMP's contribution toward its goal of a stronger, more competitive, globally-minded, and environmentally-conscious American industrial program.

I encourage your participation and use of this unique resource.

Ernie Renner
Director, Best Manufacturing Practices

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Section 1

Report Summary

Background

The International Telephone and Telegraph (ITT) Corporation was incorporated in the State of Maryland in 1920. Over the years, the corporation diversified and established facilities throughout the country. Two in particular, during the 1940s, were ITT Federal (New Jersey) and ITT Laboratories (Indiana). The latter resulted when ITT crossed paths with Philo T. Farnsworth, the inventor of electronic television. In 1939, Farnsworth had set up the Farnsworth Television and Radio Corporation in Fort Wayne, Indiana to mass produce his invention. However, unfortunate circumstances caused Farnsworth to sell his company to ITT in 1949, and become a vice president of ITT Laboratories until his retirement in 1967. During the 1960s, ITT Federal and ITT Laboratories expanded their products and services, and renamed themselves ITT Defense Communications and ITT Aerospace/Optical, respectively, to reflect their new directions. In March 1990, these facilities merged to create ITT Aerospace/Communications Division (A/CD) in Fort Wayne, Indiana — the focus of this BMP survey.

Today, ITT's corporate structure consists of its world headquarters, ITT Industries in White Plains, New York; three core divisions: ITT Automotive (Michigan), ITT Defense & Electronics (Virginia), and ITT Fluid Technology (New Jersey); and 410 facilities worldwide. At the corporate level, ITT employs 59,000 personnel and achieved $8.8 billion in sales for 1997. This diversified company designs, develops, and manufactures industrial products such as four-wheel, anti-lock brake systems; advanced technology military communications gear; geostationary imaging instruments; and giant pumps capable of emptying an Olympic-size swimming pool in 90 seconds flat. The surveyed facility, ITT A/CD, is a unit of ITT Industries and a world leader in Tactical Communications and Space Navigation/Meteorological Systems. ITT A/CD employs 2,500 personnel and achieved $500 million in sales for 1997. Among the best practices documented were ITT A/CD's commercial parts process; supplier integrated product development; surface mount device processing database; test time reduction; integrated management plan; and risk management process.

Two of ITT A/CD's most notable successes are the Advanced Very High Resolution Radiometer (AVHRR) instruments and the Single Channel Ground and Airborne Radio System (SINCGARS) devices. Despite its invaluable contributions since the 1970s, AVHRRs are relatively unknown to the general public. These instruments, which currently fly on U.S. and European satellites, provide irreplaceable data and images for accurately forecasting weather storms and patterns. AVHRRs are also now being used for non-meteorological applications such as tracking oil spills, locating schools of fish; and mapping snow melts. SINCGARS devices, another success, are highly reliable, combat net radio systems designed for the U.S. Army. Although traditional testing verifies that these radios exceed military combat requirements by five fold, it is the unofficial stories of SINCGARS that truly demonstrate the radios' durability. Flying over Panama, a transport helicopter unintentionally dropped a Light Assault Vehicle (LAV) from 500 feet, demolishing the vehicle on impact. The radio system, when removed from the wreckage and tested, functioned normally. The interior of an M113 Armored Personnel Carrier caught fire during field testing in Korea. Despite scorched paint, a melted keypad, and a cracked front panel, the radio continued to work. During maneuvers, another LAV plunged into the Atlantic Ocean off the Carolina coast, and sank so deep into the murky salt water that divers were needed to recover the vehicle. The radio remained operational, and guided the divers to the location via its illuminated front panel. For its excellent work in battlefield communications, ITT A/CD became the first recipient of the U.S. Army Communications and Electronics Command's Contractor Performance Certification in 1991.

ITT continues to enhance its world-class reputation by providing reliable, high quality products and services. The company supports this effort through engineering excellence and innovation, and thrives today as a high-technology leader with real-world impact. To maintain its leadership and position itself for the future, ITT relies on a cardinal principle — define the need, respond to that need, and then exceed the expectations. The BMP survey team considers the following practices to be among the best in industry and government.

Best Practices

The following best practices were documented at ITT A/CD:

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Commercial Parts Process — 9

In the early 1990s, commercial parts became a feasible option with attractive incentives such as lower cost, greater availability, and sufficient reliability for most applications compared to military parts. ITT A/CD established a Commercial Parts process to handle the transition from military to commercial parts throughout its defense operations. After receiving customer approval, ITT A/CD produced pilot Single Channel Ground and Airborne Radio System devices using commercial-off-the-shelf parts. These 32 pilot radios were subjected to more than 45,000 hours of Production Reliability Acceptance Testing without a single failure.

Integrated Product Development Process — 9

In 1990, ITT A/CD began implementing an Integrated Product Development process to pursue, develop, and produce all hardware, software, and systems. Known today as IPD97, this process relies on two customer-focused concepts: empowered multi-disciplinary product teams, and concurrent Integrated Product Development processes which run from proposal start through production.

National Polar-orbiting Operational Environmental Satellite System Data to Product Simulation — 10

In the past, ITT A/CD built weather satellite sensors to hardware specifications, while the government designed the software algorithms. Modeling was then tailored to specific requirements. However, radical change in customer requirements for the National Polar-orbiting Operational Environmental Satellite System required ITT A/CD to develop new design analysis techniques as well as a new system design simulator which was capable of simulating many iterations of a complex hardware/software system.

Parts List Standardization and Transfer — 10

ITT A/CD developed a company wide, on-line Product Design Components Database which contains in-house standard and commercial parts libraries. This database resolved issues and eliminated errors of the previous method, and established an across-the-board part utility tool for ITT A/CD's customers. The company also developed the Parts List Transfer Utility for Intranet use which imports information from source databases; provides a cross reference of vendors, customers, and commercial part substitution index numbers; and generates parts list reports for internal or external use.

Supplier Integrated Product Development — 11

In 1995, ITT A/CD set up the Supplier Integrated Product Development process as an improvement technique to ensure a best-value supplier selection. Designed as part of ITT A/CD's Robust Design Training program, this process fosters the involvement of suppliers throughout the Integrated Product Development process, and complements sound procurement practices such as leveraging, global sourcing, negotiations, and long-term agreements.

Dock-to-Stock Program — 11

Looking for a way to eliminate non-value added inspections, ITT A/CD developed the Dock-to-Stock program in 1996. The company uses a multi-functional team to review, evaluate, and identify parts as top performers for inclusion into the program. Acceptance information on the top performers is then loaded into a database. From this information, Dock-to-Stock material can be identified upon receipt, and sent directly to the stockroom without a formal incoming inspection.

No-Clean, Low-Residue Soldering Process — 12

In mid-1996, ITT A/CD obtained customer approvals and made the commitment to change its electronic assembly soldering and cleaning processes from a Resin Mildly Activated high solid flux and solder paste system to a No-Clean, Low-Residue Soldering process. By switching to the new process, ITT A/CD eliminated flux and thinner requirements; decreased its labor costs; and reduced volatile organic compound emissions and the handling/storage of hazardous materials.

Product Assurance Laboratory — 12

ITT A/CD developed the Product Assurance Laboratory to perform calibration and testing procedures for space, military, and commercial programs. Modeled after seven premier laboratories, the Product Assurance Laboratory is becoming widely recognized as a quality analysis laboratory that prides itself on customer satisfaction, continuous improvement, and quality service.

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Production Process Proofing Risk Assessment — 12

Production process risk assessment is the first phase of process proofing used by ITT A/CD and the Defense Contract Management Command as part of its surveillance program. To be effective, risk assessment needs to rely heavily on joint contractor/customer involvement for the overall process proofing effort. The Production Process Proofing Risk Assessment was developed to prioritize and focus on process areas with the highest programmatic risk.

Quick Reaction Center & Quick Reaction Test Facility — 13

In mid-1995, ITT A/CD established the Quick Reaction Center & Quick Reaction Test Facility to improve the transition from design engineering to manufacturing engineering. As a result, the facility has become a focal point for the Integrated Product Development process. The company also uses the Quick Reaction Center & Quick Reaction Test Facility for small production runs of boards or assemblies, rather than trying to fit them into existing manufacturing lines.

Surface Mount Device Processing Database — 13

ITT A/CD developed and implemented the Surface Mount Device Processing Database for generating surface mount device placement and touch-up processes. By combining all its Surface Mount Device processing data into one centralized automated database, ITT A/CD improved production time, reduced transcription errors, and established flexibility for component changes and machine reassignments. Since program debugging cannot begin until component feeders are loaded into the machine, the database's fast turnaround time enables ITT A/CD to start production much quicker.

Test Time Reduction — 14

An increase in production encouraged ITT A/CD to search for a way to reduce the test time and overall cost of its testing program. Sampling seemed to be a logical choice to accomplish these goals and still produce a quality product. Based on MIL-STD-105, ITT A/CD implemented three types of sample testing: Continuous Sampling; Parameter Sample Testing; and No Testing. In addition, the company developed a Test Time Reduction philosophy to ensure that a reduction in testing would not impact the quality and reliability of the product.

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Spares, Repairs, and Support — 15

ITT A/CD established a dedicated logistics spares order processing and tracking organization which significantly improved customer satisfaction, and reduced the manufacturing spares order release and processing time. Features of the Spares, Repairs, and Support include a multifunctional Spares/Repairs Order Processing Core team colocated with the manufacturing operations; a Logistic Customer Response Center to organize and prioritize responses; and a logistics order tracking database.

Advanced Process Development — 15

ITT A/CD implemented Advanced Process Development as a structured approach to process development which addresses critical and complex manufacturing process development tasks. This approach also provides a structured and proven methodology to ensure that processes operate efficiently, effectively, and at the best value.

Business Development Process — 17

ITT A/CD's Business Development Process is a very effective, integrated proposal process that was started about five years ago. This process shifts much of the focus and resource expenditure to the front end of a project. In January 1997, ITT A/CD formally integrated the Business Development Process with its Integrated Product Development process, enabling the company to fully involve its Business, Engineering, Operations, Finance, and Contracts departments up front at the bid and proposal stages.

Common Process Management Council — 18

In 1995, ITT A/CD and the Defense Contract Management Command formed the Common Process Management Council as a joint contractor/customer management team. The council provides support for the Commercialization and Acquisition Reform Initiative; charters and facilitates Process Oriented Contract Administration Services teams; reviews and approves submission of Single Process Initiatives and block-change requests; assigns resources; and reviews status on process improvements.

Earned Value Management System — 18

In a cooperative effort with various government agencies, ITT A/CD developed and implemented the Earned Value Management System. This management control system is used for current and future Research Development Test and Engineering and production contracts that are valued at more than $500,000.

Item	Page
Integrated Management Plan	18

ITT A/CD developed and implemented a disciplined and comprehensive planning tool called Integrated Management Plan to communicate, coordinate, and document all elements of a program from concept to completion. Key elements of the process include: program overview; key assumptions; inter-program crossfeeds and dependencies; performance characteristics; team deliverables; tailored design process; top-level schedule; financials; risk register; operations approach; preliminary project plans; staffing; contracts; and customer involvement.

Program Launch Process	19

In 1997, ITT A/CD established the Program Launch process as an organized method to ensure that budgets, schedules, resources, equipment, facilities, and materials required for launching new programs are identified, planned, and implemented prior to production. The core team's creed is to talk, think, collaborate, plan, document, concur, and launch.

Risk Management Process	20

In 1994, the company set up a formal Risk Management process to identify and eliminate potential problems before they can impact the completion of a program. The process works as an integral part of the Product Development process, and evaluates all facets of risk items such as hardware, software, and programmatic components.

Technology Roadmap	20

In 1992, ITT A/CD's Operations Engineering introduced the Technology Roadmap as a vehicle for tracking technology trends, requirements, and execution. The roadmap is an integrated master plan to track the critical manufacturing and test technology needs for current and future programs relative to the Manufacturing for Design initiative. Updated and maintained in real time, the Technology Roadmap documents where technology is going relative to business requirements for a three- to five-year period.

Video Production Facility	21

ITT A/CD established a Video Production Facility to eliminate its reliance on outside vendors, decrease its turnaround time for a finished product, and alleviate its tight departmental budgets. This state-of-the-art facility handles all aspects of video production; produces quality training and commercial videos for internal and external customers; and has won numerous commercial and film awards.

Information

The following information items were documented at ITT A/CD:

Item	Page
Design Review Manual	23

ITT A/CD's Design Engineering Group recently updated its design review process by implementing an automated, on-line version of the Design Review Manual. By automating this manual, ITT A/CD eliminated bulky documentation, increased employee participation, and provided users with a real-time review of current design requirements.

Design-to-Cost Reduction Planning	23

ITT A/CD established Design-to-Cost Reduction Planning to meet changing customer contract objectives and to compete more aggressively. This structured system integrates all elements of the design and manufacturing processes; allows unit production costs to be determined as part of the design phase; provides objective measurements of Integrated Product Development outputs; fosters organizational culture change; and promotes innovative thinking.

End-to-End Modeling	23

ITT A/CD developed End-to-End Modeling to perform design analyses on complex product development projects such as minimizing the distortion of geostationary scanning mirrors. This analytical modeling method allows engineers to evaluate numerous design alternatives and assess conflicting design tradeoffs.

Peer Review	24

ITT A/CD's Design Engineering instituted Peer Review as an initiative to establish a documented, informal, design review process. Design engineers invite operations experts and experienced engineers from various departments to attend informal presentations and evaluate their proposed designs.

Rapid Prototyping	24

ITT A/CD developed Rapid Prototyping to shorten its mechanical design/development cycle time and to improve the success of first-article environmental tests. This process uses an electronic suite of software tools to quickly produce a prototype, which provides the engineer with additional time to consider tradeoffs and alternative evaluations. The result is a higher quality final product.

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Robust System Design Process 25

Robust refers to designs that perform in the customers' environments according to their expectations. ITT A/CD's Robust System Design process is a total life cycle approach that uses a series of methods and techniques which complement the design process. These methods and techniques are well established reliability design tools that help design engineers identify needs, and address critical factors during the design stages of the product.

Technical Performance Measures 25

ITT A/CD developed Technical Performance Measures as a rational way to assure ultimate system performance, quality, and customer satisfaction. These measures consist of metrics (e.g., expected value, allowed margins, parameter variations over time) which are developed from requirement prioritization, program experience, and quality function deployment.

Automated Test Equipment Review and Validation 26

ITT A/CD developed the Automated Test Equipment Review and Validation process based on the Integrated Product Development team approach and use of peer reviews. Since implementing this process, ITT A/CD has increased communication and mutual understanding among its functional organizations; reduced debugging time; created a robust, standardized design procedure; and ensured all tests are performed.

Field Feedback 26

ITT A/CD developed a Field Feedback program to deal with product issues during a military fielding operation. The company designed a long-term/permanent vehicle for handling the exchange of information between ITT A/CD and the field site. In addition, ITT A/CD implemented on-site field service representatives to address open and closed maintenance actions; discuss equipment problems; and supply configuration information on the number of units serviced at the field site.

Production Reliability Acceptance Testing 26

ITT A/CD uses Production Reliability Acceptance Testing to demonstrate successful subsystem operation in simulated field environments, and to verify compliance with contractual reliability requirements. This aggressive testing also confirms consistency in the product's manufacturing processes, and identifies changes in the component's quality or supplier's manufacturing processes.

Chemical Reduction Program 27

In 1991, ITT A/CD initiated a Chemical Reduction program to regulate hazardous chemicals being used in its manufacturing process, and establish a cleaner, healthier environment for its employees. To aid in this effort, the company established a Chemical Review Board.

Defect Analysis Team 27

ITT A/CD established the Defect Analysis Team as a governing body to assure in-circuit yield improvements. This cross-functional team set up a four-level defect pareto analysis based on in-circuit yields: Level One is In-Circuit Yield History, consisting of all boards; Level Two is In-Circuit Defect Trends, broken down by assemblies, components, solder, and miscellaneous; Level Three is a break-down of each level two attribute; and Level Four is a listing of all defects.

Failure Reporting, Analysis, and Corrective Action System 28

ITT A/CD developed the Failure Reporting, Analysis, and Corrective Action System to handle failures, analyses, and corrective actions of units. This automated system has reduced the company's data entry and analysis time from several weeks to a few seconds.

Failure Reporting, Analysis, and Corrective Action System for Electro Optical Space Projects 28

ITT A/CD developed the Failure Reporting, Analysis, and Corrective Action System for Electro Optical Space Projects as a means of documenting, analyzing, tracking, and resolving incidents that occur on space projects. This dynamic system provides the company with flexibility to perform efficient failure reporting, disposition, and closure.

Filter Housing Process Development 28

ITT A/CD established a state-of-the art model/machine shop which can produce very small tolerance products. Equipped with computer numerically controlled machining capabilities and automated process generation and verification, this facility is also used for short turnaround and unique build requirements.

Item	Page
Fully Automated Testing	29

ITT A/CD wanted a method that would reduce test manpower but improve efficiency, decrease cost, and meet production increases. After examining potential techniques, the company chose automated testing as the primary method for this effort. ITT A/CD has designed an automated test cell for use in its military radio production which will significantly reduce manpower.

Manufacturing Confidence Evaluation	29

ITT A/CD developed the Manufacturing Confidence Evaluation process as a way to tailor manufacturing screens used during production. This approach obtains the greatest benefit for a level of expenditure, and precipitates workmanship and manufacturing defects as early as practical in the production cycle.

Postmortem Process	30

ITT A/CD developed the Postmortem Process to improve the manufacturability and testability of products built in the Quick Reaction Center. In addition, the process identifies consistent issues, and tracks the progress in resolving problems.

Product Assurance Requirements Definition	30

Product Assurance Requirements Definition is a process which documents supplier quality requirements as detailed by specifications, internal procedures, and the contract. In addition, this process works as an agreement between Quality Engineering; Procurement; Purchased Material Inspection; and Supplier Support and Development.

Re-engineered Test Program	30

Prior to NASA launching each Geostationary Operational Environmental Satellite, ITT A/CD used a test system to collect data from the satellite's instruments to verify they were properly working. As newer programs were started, ITT A/CD and NASA recognized the need to improve the test system. Currently, the company is in the final design and assembly stages of the Re-engineered Test Program.

Test Equipment Integration	31

ITT A/CD's Logistics Division supports various programs by being involved in the redesign, test, monitoring, and control of complex projects as well as providing coordination and direction, and interacting with internal and external customers. This involvement in Test Equipment Integration has led to many successful programs.

Item	Page
American Express Procurement Card Program	31

In mid-1996, ITT A/CD implemented the American Express Procurement Card program which simplified the procurement process, improved productivity, enhanced internal controls, increased customer satisfaction, and achieved significant savings. Through this program, ITT A/CD now completes more than 5,000 small purchase orders per year, and achieved a total annual savings of $785,000.

Engineering Development Program	32

In January 1998, ITT A/CD established the Engineering Development Program. This program formally trains recent engineering graduates as future engineers through a two-year effort of rotational assignments and cross-functional training.

Manufacturing for Design Initiative	32

ITT A/CD's Manufacturing for Design initiative places special emphasis on developing critical manufacturing and test technologies prior to the start of detailed designing. This approach allows product designs to be done in a reliable, robust, and cost-effective manner over a shorter period of time and at the best value.

Operator Self Inspection Program	33

In 1996, ITT A/CD established the Operator Self Inspection program to integrate the inspection step into the production process, verify instruction documentation by the end user, and strengthen build-to-print capabilities. By checking the product as it is being produced, operators can identify problem indicators early in the process, and minimize waste, redundancy, and rework.

Small Business Program	33

Small business programs are designed to promote performance opportunities for those businesses categorized as small; small disadvantaged; and women-owned small. Through its Small Business program, ITT A/CD established a standardized process to handle small business plans and review internal performance; set up a procurement team to address utilization performance; and developed a small business library to identify small business opportunities.

Point of Contact

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Section 2

Best Practices

Design

Commercial Parts Process

Previously, ITT Aerospace/Communications Division (A/CD) used only military parts in its defense projects. These MIL-STD-883 screened parts were chosen by design engineers and bought by the Procurement department. Vendors were located by component engineers. In the early 1990s, commercial parts became a feasible option with attractive incentives such as lower cost, greater availability, and sufficient reliability for most applications compared to military parts. ITT A/CD established a multi-functional team to assess the transition from military to commercial parts throughout its defense operations.

The team initiated a Commercial Parts process by developing a qualification plan for procurement. Through the plan, the team conducted surveys, visited vendors, and reviewed parts data to address specific plastic encapsulated microcircuit and non-military concerns (e.g., lifetime cost, reliability, performance). Commercial part samples were also analyzed via destructive physical and soniscan analyses at ITT A/CD. This process enabled the company to develop a working preferred supplier list, and determine the critical parameters and specific application requirements of commercial parts.

After receiving customer approval, ITT A/CD produced pilot Single Channel Ground and Airborne Radio System (SINCGARS) devices using commercial-off-the-shelf (COTS) parts. These 32 pilot radios were subjected to more than 45,000 hours of Production Reliability Acceptance Testing (PRAT) without a single failure. Additionally, ITT A/CD ran comparison PRATs (156,500 hours) on SINCGARS military and COTS radios. The results indicated that the COTS radios were at least as good as the military radios. In November 1997, ITT A/CD initiated a COTS supplier dock-to-stock program. As of December 1997, the company fielded 40,000 SINCGARS COTS radios and estimates 126,000 radios will be in the field by the year 2000. To date, only one field failure related to COTS parts has occurred.

The Commercial Parts process enables ITT A/CD to produce cost effective and reliable products by using commercial parts instead of military ones. In the case of SINCGARS radios (Figure 2-1), COTS parts reduced material cost by 50%, increased part availability by tenfold, and achieved reliability equivalent to military parts. In addition, the use of COTS parts eliminated the required test screens and control of detailed drawings of military parts.

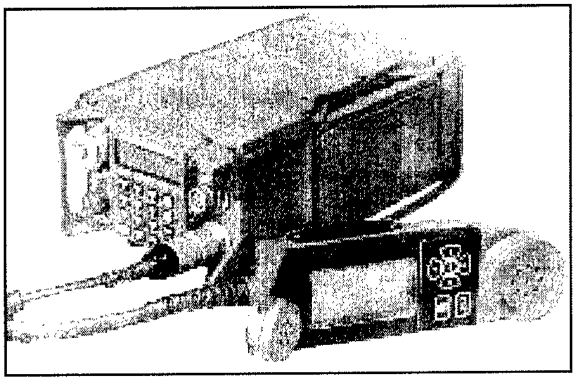

Figure 2-1. SINCGARS Radio with Handset

Integrated Product Development Process

Previously, ITT A/CD used a traditional functional matrix organization approach for its product development efforts. In 1990, the company began implementing an Integrated Product Development (IPD) process to pursue, develop, and produce all hardware, software, and systems. Over the years, ITT A/CD continuously improved this process, and today uses a version known as IPD97.

IPD97 relies on two customer-focused concepts: empowered multi-disciplinary product teams, and concurrent IPD processes which run from proposal start through production. The teams, known as Integrated Product Teams (IPTs), are comprised of representatives from each functional organization who can voice an opinion throughout the development and production cycles. By using IPTs, ITT A/CD eliminated the traditional method where each functional organization completed its task sequentially and passed the results to the next organization. The IPD process is also supported by top-level leadership, and enables the company to establish clear IPD process and project goals (e.g., proactive risk management, robust development, process improvement). ITT A/CD uses seamless project management tools, and devel-

oped a bridge between Microsoft Project and MicroFrame for the IPD process.

Management support and the integration of development and production processes help make the IPD process successful at ITT A/CD. The IPD process reduces product development cycle time, lowers overall product cost, and establishes an environment in which the employees can succeed. Since implementing the process, ITT A/CD reduced its typical product development cycle time from two-and-a-half years to just one year. In addition, the number of simultaneous ongoing programs has increased from 15 programs in 1993 to 40 programs in 1998. Other benefits include smoother transitions to production and improved quality of designs and products.

National Polar-orbiting Operational Environmental Satellite System Data to Product Simulation

In the past, ITT A/CD built weather satellite sensors to hardware specifications, while the government designed the software algorithms. Modeling was specifically tailored for various hardware requirements (e.g., radiometry, optics, structural). However, radical change in customer requirements for the National Polar-orbiting Operational Environmental Satellite System (NPOESS) required ITT A/CD to develop new design analysis techniques. For this next-generation satellite, only the results expected from the system via 28 environmental data records (EDRs) were specified. EDRs are the useable products (e.g., images, temperature, cloud cover, moisture profiles) which are translated from raw sensor data by satellite hardware and software algorithms. ITT A/CD had to devise a new system design simulator which was capable of simulating many iterations of a complex hardware/software system.

Although the requirements of the NPOESS sensor are derived via physics to compute the EDR parameter of interest, the system (consisting of the algorithmic software and the sensor) must meet the system EDR requirements. Performance against each EDR parameter must be evaluated for all EDRs. To verify the NPOESS system performance against the 28 EDR product specifications, a very flexible simulation tool was needed to simulate the input data, the sensors, and each of the EDR algorithmic software elements. Extensive analysis of the simulation results to derive the performance levels was also required. ITT A/CD, along with Nichols Research Corporation, developed the FlexSim simulator for this purpose.

FlexSim is based on object oriented programming principles using C++, and provides a very flexible, modular framework for simulation. Other contractors on the NPOESS program contribute system components and provide subsystem simulation models to ITT A/CD which must be integrated into the system simulation. FlexSim provides this flexibility, allowing models built from many software languages to be integrated and various computer hosts including PCs to be used. Another challenging aspect of the NPOESS development is the input data for simulation. Since NPOESS has no existing source from which to receive actual input data, ITT A/CD must either derive data from sources with similar information or create data from scratch. Extreme care must be taken to account for errors which may be introduced in the data due to the derivations. In addition, the huge size (gigabyte range) of the input databases is a complicating factor.

By using FlexSim and its modular simulation approach, ITT A/CD can accommodate the developmental nature of the NPOESS system design, allowing the rapid assembly of a simulation from modules. The NPOESS system level performance can also be verified by this approach. Cost and performance tradeoff studies will enable ITT A/CD to choose the optimum conceptual approach. This tool is being applied to new and old programs, giving customers new information about their designs.

Parts List Standardization and Transfer

ITT A/CD previously used a hard copy standard components directory and approved parts list. Based on military standard parts and arranged by project or group designs, these guidance tools provided good general information, but lacked part number specifications and tended to become outdated. In addition, external customer requirements drove part specifications, imposed cost restraints, and failed to address specific critical system needs. These issues, plus the trend toward commercial parts, amplified the company's need for a common parts database. In response, ITT A/CD developed a company wide, on-line Product Design Components Database (PDCD) which contains in-house standard and commercial parts libraries. PDCD resolved issues and eliminated errors of the previous method, and established an across-the-board part utility tool for ITT A/CD's customers.

ITT A/CD also developed the Parts List Transfer Utility (PLTU) for Intranet use through Microsoft Access software. The PLTU imports information

from source databases (e.g., PDCD, electrical, mechanical) and exports the parts list data to other systems (e.g., material requirements planning, cost database). This utility also provides a cross reference of vendors, customers, and commercial part substitution index numbers, and can generate parts list reports for internal or external use. For easy accessibility of the PLTU, employees use the Top Drawing Index (TDI) tool. Among the TDI tool's functions are capturing and maintaining product hierarchical family trees and individual components; creating indentured top-down lists of all assemblies required to compose a product; providing search capability; identifying duplicate assemblies or part numbers; and maintaining individual parts cost throughout the utility.

The PLTU is used throughout ITT A/CD from initial design through development to production. This utility establishes a state-of-the-art, real-time access standard parts process and higher reliability for parts usage and operations across all projects. The bill of materials (BOMs) database is also maintained on the PLTU. This new feature saves numerous hours of labor by eliminating manual data entry and potential human errors. By using its parts list standardization and transfer tools, ITT A/CD now accesses current information, decreases cycle time, reduces risk, and predicts more accurate project costs. The ease of accessibility and real-time control process for continuous updating allows for commercial part substitution across all projects, which has become increasingly significant due to the decreasing part life cycle.

Supplier Integrated Product Development

In 1995, ITT A/CD set up the Supplier Integrated Product Development (SIPD) process as an improvement technique to ensure a best-value supplier selection. Prior to this process, the company did involve critical suppliers in the IPD process, but inconsistently tracked best-value measurements. Designed as part of ITT A/CD's Robust Design Training program, the SIPD process fosters the involvement of suppliers throughout the IPD process.

The SIPD process starts with the selection of a multi-functional team and a senior staff advisor. The team defines its objectives, identifies key part numbers, and selects candidate suppliers. The next phase involves initiating supplier briefings, establishing non-disclosure agreements, and assigning tasks to team members. The SIPD process uses a team approach to address all elements (e.g., design, costs, schedule, quality, supportability, customer expectations) throughout a product's life cycle, and to work on key issues established by the team members.

During the concept/development phase of the SIPD process, the team develops a winning proposal position via design-to-cost and cycle time reduction strategies. The team's focus is to match supplier solutions to program requirements, establish supplier alliances, and make a best-value supplier selection. Early involvement of the supplier is a key aspect of the process. During the production phase of the SIPD process, the team determines how to reduce cycle time and cost. The team's focus is to eliminate non-value added requirements and replace these with supplier process improvements.

The SIPD process complements sound procurement practices such as leveraging, global sourcing, negotiations, and long-term agreements. In return, ITT A/CD obtains design improvements; robustness; cycle time and cost reductions; improved quality and reliability; and maintainability. By using the SIPD process, ITT A/CD reduced its costs by 10% between 1995 and 1997, and estimates an additional 10% reduction between 1997 and 1999.

Production

Dock-to-Stock Program

Previously, ITT A/CD's Purchased Material Inspection (PMI) department tested samples from all incoming part lots regardless of quality history. The company's inspection philosophy was primarily reactive, and any decision to waive an inspection was made solely by PMI engineers. During its efforts to reduce cost and increase throughput, ITT A/CD determined that receipt inspections were being performed on parts with excellent quality histories. Looking for a way to eliminate non-value added inspections, ITT A/CD developed the Dock-to-Stock (DTS) program in 1996.

ITT A/CD uses a multi-functional team of component, quality, reliability, manufacturing, and supply liaison engineers to review each part's incoming acceptance history. The top performers are then submitted for further evaluation. Once the team approves a part for inclusion into the DTS program, the part's acceptance information is loaded into a database. The database is used to identify DTS material upon receipt, enabling these parts to be sent directly to the stockroom without a formal incoming inspection. ITT A/CD also uses a tracking system to maintain and update all material acceptance information.

Since implementing its DTS program, ITT A/CD realized a cost savings of approximately $134,000 in 1996 and $225,000 in 1997. The company now focuses inspections on critical parts and problem suppliers. This effort resulted in a constant decrease in cost per lot from $85 in 1996 to $58 in 1998. ITT A/CD's inspection philosophy is becoming proactive, and the top performing suppliers are being identified, recognized, and used on future orders.

No-Clean, Low-Residue Soldering Process

In 1993, ITT A/CD approached its customers and proposed changing the electronic assembly soldering and cleaning processes at the company. Based on environmental, process improvement, and cost reduction issues, ITT A/CD wanted to switch from a Resin Mildly Activated (RMA) high solid flux and solder paste system to a No-Clean, Low-Residue Soldering process. In mid-1996, the company obtained customer approvals, and made the commitment to change to the new process.

The RMA-based system required operators to thin the high solid flux with isopropanol alcohol approximately twice per shift for the RMA-based wavesolder machines. In addition, these older machines used a thinning oil which made cleaning difficult. Maintenance was continual with filter changes; flow level checks; impure solvent changes; holding tank cleaning; and pumps and blower upkeep. In January 1998, a new Delta wavesolder machine was brought on-line to replace the two RMA-based wavesolder machines and associated in-line cleaners and solvents, and reduce upkeep, emissions, and waste. By switching to a No-Clean, Low-Residue Soldering process, ITT A/CD eliminated the RMA flux and thinner requirements. The new process also reduced the company's volatile organic compound emissions and the handling/storage of hazardous materials. A two-fold increase in throughput was realized for the soldering process, and the elimination of RMA-based cleaning procedures improved ITT A/CD's cycle times by approximately 30 minutes.

Since implementing its No-Clean, Low-Residue Soldering process, ITT A/CD saved approximately $700,000. Other benefits include reduced labor costs and the elimination of semi-aqueous in-line cleaners; thinning oil; flux chemical mixing; and titanium, nitrate-coated Z-wave baffles. Although all previous emission levels at ITT A/CD met Indiana standards, the new wavesolder process reduced the company's emissions by 38 tons per year.

Product Assurance Laboratory

ITT A/CD developed the Product Assurance Laboratory (PAL) to perform calibration and testing procedures (e.g., failure analysis, construction analysis, re-certification) for space, military, and commercial programs. The company has been cultivating PAL's in-house capability since 1988 when the initial laboratory consisted of a few work areas and seven people. Prior to PAL, ITT A/CD contracted most of its laboratory work to independent facilities. Today, PAL has been expanded to more than 6,000 square feet.

During the developmental phases of PAL, ITT A/CD spent considerable time and effort in surveying and identifying capabilities outside of the company. More than 500 surveys were sent to independent laboratories to request benchmarking partnerships. From these surveys, ITT A/CD selected seven premier laboratories (e.g., Cray Research, IBM Materials Laboratory, Motorola AIEG) from which to model PAL. PAL handles various commodities such as active discrete and passive devices; hybrids and integrated circuits; fasteners; coatings; and electro-mechanical connectors, switches, and relays. Specialized equipment used at PAL include C-mode scanning acoustic microscopes, scanning electron microscopes, energy dispersion x-ray analyses, atomic absorbers, and ultraviolet/visible spectrophotometers.

ITT A/CD's PAL is becoming widely recognized as a quality analysis laboratory, and prides itself on customer satisfaction, continuous improvement, and quality service. In 1997, the laboratory's customer satisfaction level reached 99.6%. Besides its in-house responsibilities to ITT A/CD, PAL has begun contracting its services to other companies.

Production Process Proofing Risk Assessment

Production process risk assessment is the first phase of process proofing used by ITT A/CD and the Defense Contract Management Command (DCMC) as part of its surveillance program. To be effective, risk assessment needs to rely heavily on joint contractor/customer involvement for the overall process proofing effort. The Production Process Proofing Risk Assessment (PPPRA) was developed to prioritize and focus on process areas with the highest programmatic risk. Prior to the PPPRA process, ITT A/CD and the DCMC prioritized their efforts independent of one another, which often led to conflicting strategies. Neither had a complete understanding of the other's role, responsibilities, or concerns.

Using a team approach, the PPPRA process identifies the greatest relative importance of the program so ITT A/CD and the DCMC can focus their efforts. The team first reviews the contract requirements to establish baseline priorities for the program. Next, the team examines the floor layout, identifies available processes, and flowcharts the overall process/product sequence. A generic master list of product characteristics is then developed based on potential risks to ITT A/CD and the DCMC. Next, the team selects the appropriate product characteristics (limit of ten) from the generic master list, and the key measurable processes from the flowchart. This data is constructed as a matrix (characteristics versus processes) in a risk analysis chart. Each characteristic is assigned a subjective importance factor from one to five (five is high) based on its significance to the program. Each process receives a risk level per characteristic using one as low, two as medium, and three as high. From these assigned values, the relative importance of each process can be calculated by multiplying the importance factor by the risk level, and then summing that process' column.

The PPPRA process provides many benefits to ITT A/CD and the DCMC. Among these are common focus; synergism of effort; process requirement prioritization; improved communication; shared information; and a better awareness of each other's role.

Quick Reaction Center & Quick Reaction Test Facility

In mid-1995, ITT A/CD established the Quick Reaction Center (QRC) & Quick Reaction Test (QRT) Facility to improve the transition from design engineering to manufacturing engineering. Prior to the QRC & QRT Facility, the company operated the Advanced Manufacturing Engineering Laboratory with one engineer and one technician. Although it lacked specific test capabilities, the Laboratory could verify design readiness; provide internal research and development efforts; build small quantities of boards; and prove out processes.

The QRC & QRT Facility consists of 15 operators, one supervisor, and four to five manufacturing engineers on call. The staff receives cross-training in multiple procedures and operations. Typical capabilities of the Facility include reviewing engineering drawings and parts lists; performing part verification; providing test capabilities; examining special assembly instructions; identifying and documenting problems; and making suggestions for improvements. ITT A/CD also uses the QRC & QRT Facility for small production runs of boards or assemblies, rather than trying to fit them into existing manufacturing lines.

ITT A/CD's QRC & QRT Facility has improved communications between design engineering and manufacturing engineering, and become a focal point for the IPD process. Other benefits include early identification of documentation issues, quicker cut-in of manufacturing improvements, reduced transition times, and elimination of small project congestion in manufacturing.

Surface Mount Device Processing Database

ITT A/CD developed and implemented the Surface Mount Device Processing Database (SMD-PD) for generating SMD placement and touch-up processes. By combining all its SMD processing data into one centralized automated database, ITT A/CD improved production time, reduced transcription errors, and established flexibility for component changes and machine reassignments. The company's previous method was often inaccurate, required numerous hours to produce documentation, and could not keep up with changes and reassignments.

The SMD-PD takes advantage of two existing files: (1) the .MFG file which contains the reference designators and pad locations for each board and part; and (2) the .BOM file which contains the bill of materials for each board. By preparing and combining these files, operators can quickly and accurately generate the feederset index, the placement process, and the feeder labels. Figure 2-2 shows how to create an SMD placement process. Previously, operators had to manually and repeatedly enter part numbers for each assembly. Since some assemblies have more than 300 parts, this procedure required numerous hours. Now, the operators only need to enter each part once into the Master Table of the SMD-PD. Part numbers needed for a parts list are then imported directly from the Master Table, eliminating transcription errors. Once the final placement program is created, the operators produce the finished placement process within 30 minutes, including the feederset index, the actual process pages, and the feeder labels required by new component assignments. The previous method performed the same feat in about eight hours. The SMD-PD also provides substantial flexibility in machine reassignments, and process or part number changes.

The SMD-PD's built-in queries allow the operator to obtain extensive information on component usage such as an SMD parts list for any assembly; all assemblies which use a particular component; case

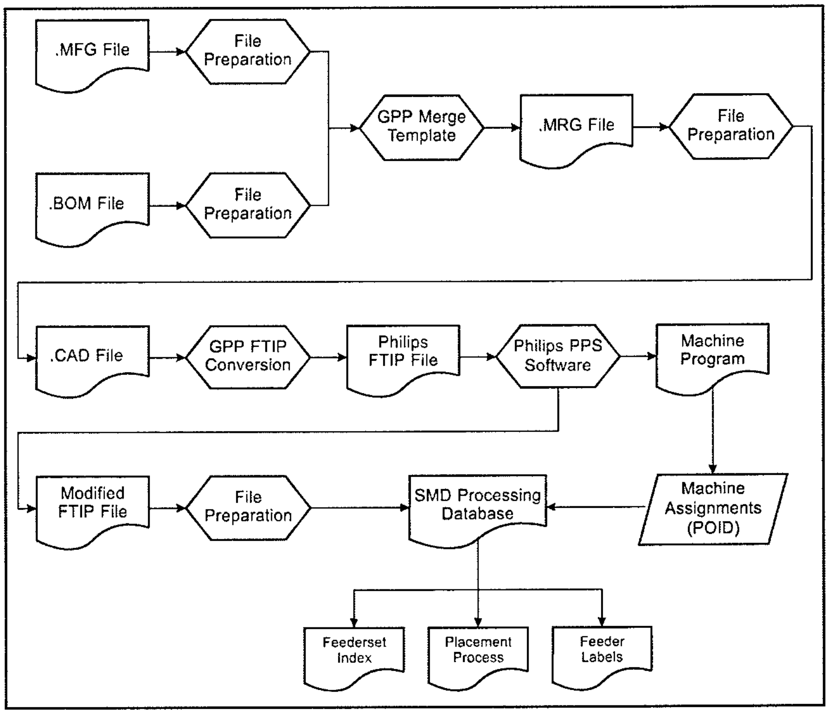

Figure 2-2. Creating an SMD Placement Process

size, lead count, and lead configuration of a part; reference designators for a particular component; and components used on a particular production program. A reference copy of the SMD-PD resides in a shared directory on the company's server, allowing accessibility throughout the facility.

The SMD-PD provides a well-established, accurate, and quick method to generate SMD placement and touch-up processes. Since program debugging cannot begin until component feeders are loaded into the machine, the database's fast turnaround time enables ITT A/CD to start production much quicker. In addition, the SMD-PD is a valuable analytical tool that can be used in SMD manufacturing process studies.

Test Time Reduction

An increase in production encouraged ITT A/CD to search for a way to reduce the test time and overall cost of its testing program. Sampling seemed to be a logical choice to accomplish these goals and still produce a quality product. The company recognized the usefulness of testing as well as the quantity of knowledge gained (e.g., process health via in-circuit testing, materials quality via functional testing, design robustness via environmental testing). The company developed a Test Time Reduction philosophy to ensure that a reduction in testing would not impact the quality and reliability of the product. This philosophy states:

- When a test stops providing useful knowledge about the product, it no longer has value and should be eliminated or executed on a sampling basis.
- Test yields must support test reduction by using parametric and attribute data collection.
- Sampling must not impact the quality or acceptance testing of the product.
- Sampling cannot create additional requirements at another location or push a problem to a higher level.
- The organization must have a commitment to the program and yield improvements.

Based on MIL-STD-105, ITT A/CD implemented three types of sample testing. These consist of (1) Continuous Sampling which alternates between 100% testing and sample testing; (2) Parameter Sample Testing where each unit receives a particular set of tests, and all other parameters are subjected to sample testing; and (3) No Testing where yields are monitored at the next higher assembly test.

Continuous Sampling involves selecting three units from a lot of ten. If any of the three units fail, then the entire lot is fully tested. If all pass, then the remaining seven are recorded in the system by scanning their internal control codes. ITT A/CD processes five lots in this manner, and the resource manager keeps track of the attribute data. If any two of the last five lots fail, then the system puts testing of that unit into a controlled condition where all units receive 100% testing until five consecutive lots have a 100% yield history.

Parameter Sampling Testing also involves a lot of ten units. Three units receive full-scale testing while the remaining seven only get critical parameter testing. A critical parameter is defined as a parameter that does not receive a test anywhere else in the flow, deemed as part of a reliability critical process, and has a yield problem. Like Continuous Sampling, the resource manager keeps track of the attribute data, and if any failures occur, the same five lot approach is used.

In No Testing, yields and troubleshoot information are monitored at the next higher assembly test. A test engineer monitors the yield data at the radio level,

and instructs the system on whether or not to perform testing. Efficiency is based on the skill of the test engineer.

Currently, ITT A/CD uses the Test Time Reduction process on three products. The test time reductions were, respectively, 2.5 hours to less than one hour; 5.8 hours to less than 3.5 hours; and 0.9 hour to 0.4 hour. These results can become significant time savings for large in-house production programs at ITT A/CD. The company estimated one contract as having a potential savings of 16,392 test hours over a 35,000-quantity radio build.

Logistics

Spares, Repairs, and Support

Prior to 1991, ITT A/CD's Spares and Repairs Support for its military radio program received little interest or attention from either the customer or the company. This attitude was due partly to the excellent reliability of the product as well as the shortcomings of the acquisition system that handled spares and repairs. From ITT A/CD's perspective, Spares and Repairs Support only achieved about $1 to $4 million in annual revenue, and was not considered a high priority compared to production schedule deadlines for operational units. This outlook was reflected by a low (50% to 60%) on-time delivery performance for spares and repairs; the absence of a management system for spares order definition, tracking, and prioritizing; and the lack of a formal process or single point of contact for fielding, directing, and responding to inquiries. Customers with problems were essentially handed off and passed from department to department without getting satisfactory resolution. Excessive internal time and costs were being incurred to develop price and repair cost estimates because of inadequate and inaccessible cost data for spares, repairs, and integration support.

By 1991, strong customer dissatisfaction was becoming apparent, and management became devoted to resolving the situation. Improving customer satisfaction was the primary goal, and the company assigned this task to the Integrated Logistics Support (ILS) department. The ILS team established objectives which included improving delivery performance; providing a focal point for screening and processing inquiries; decreasing response time to customer inquiries; lowering bid costs; developing a standard cost database for spares and repairs support; reducing spares production processing time; and capturing sales of production surplus.

To achieve these results, ITT A/CD set up a dedicated organization. First, a Spares/Repairs Order Processing Core team was formed using representatives from the Logistics, Manufacturing, and Contracts departments, and colocated with the manufacturing operations in the production facility. Next, the company installed a logistics order tracking database for spares, repairs, and support. Spares and repairs inquiries are now routed to the newly established Logistic Customer Response Center, where a logistics customer relations coordinator organizes and prioritizes the responses. In addition, all spares, repairs, and integration support proposals are processed by logistics program management and the manager of customer relations for approval and transmission to the customer.

As a result of these improvements, ITT A/CD now has a dedicated logistics spares order processing and tracking organization which significantly improved customer satisfaction, and reduced the manufacturing spares order release and processing time. Since 1991, the company's spares on-time delivery performance has increased from 50% to 99%, while its bid and proposal costs for spares have dropped by 25%. ITT A/CD also reduced its customer inquiry time from an average of 48 hours to less than 24 hours. The growth in order processing capability and the quick customer response time has increased the company's sales revenue in Spares, Repairs, and Support from $4 million to nearly $25 million.

Management

Advanced Process Development

ITT A/CD implemented Advanced Process Development (APD) as a structured approach to process development which addresses critical and complex manufacturing process development tasks. This approach also provides a structured and proven methodology to ensure that processes operate efficiently, effectively, and at the best value. Prior to this system, no formal process existed. Young engineers lacked training in successful methods, and most process development efforts were shortsighted. Solutions neither satisfied long term requirements nor supported accelerated product development cycle times. Revising process planning was common. The process was inefficient and ineffective because tools of quality were not applied, solutions came before understanding, and planners did not capitalize on previous knowledge.

As a well-defined and structured process, APD (Figure 2-3) sets the stage for responsibility because it is customer driven and multifunctional. The process encourages innovation, and requires planners to learn by investigating existing knowledge bases, benchmarking, teaming, and interfunctional brainstorming. However, pioneering can be costly, so emphasis is placed on modifying existing processes that work, rather than developing new and unproven processes. Tools of quality (e.g., Taguchi methods, design of experiments, fishbone diagrams, brainstorming) are relied on extensively, and ensure that engineers address essential factors such as life cycle cost; voice of the customer; quantitative measurement; budget and schedule constraints; and risk management.

In developing the process, ITT A/CD learned that APD requires a flexible but structured approach. Since the process is designed to be tailored, APD acts as a guide and does not stifle innovation and creativity. However, APD is neither an alternative to project management nor an intuitive method. Employees must have effective management skills and training in the tools of quality to make the process work. ITT A/CD has achieved excellent results with this process. Application of APD in major programs resulted in significant and continuing reductions in the average time to develop advanced processes from 44 weeks in 1996 to 33 weeks in 1997. The goal for 1998 is 25 weeks.

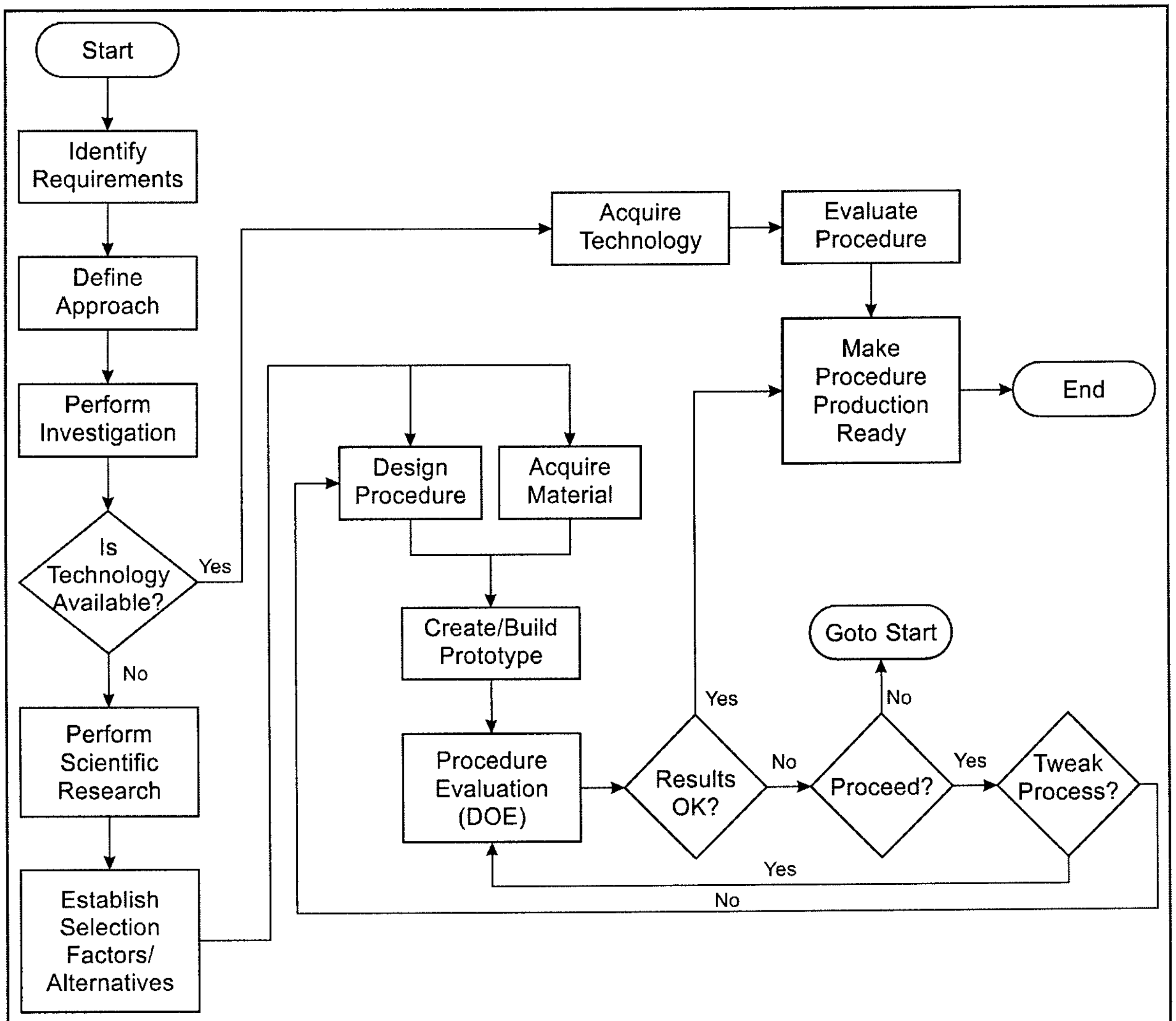

Figure 2-3. Advanced Process Development Flow

Business Development Process

ITT A/CD's Business Development Process is a very effective, integrated proposal process that was started about five years ago. As the initial phase of the IPD process, the Business Development Process shifts much of the focus and resource expenditure to the front end of a project. Prior to the early 1990s, no formal business development process existed. The company relied on basic business development practices, and effectively raised its win rate from 30%-40% to 70%-80%. However, ITT A/CD realized that it was writing good proposals and winning contracts without any comprehensive plans for implementing or successfully completing them. These basic practices were also only being applied to large programs. ITT A/CD wanted to standardize and integrate a business development process into its corporate policies and other IPD initiatives. In January 1997, the Business Development Process was formally integrated with the company's IPD process, simplified, and more strongly enforced. These changes enabled ITT A/CD to improve the entire IPD process.

By integrating the Business Development Process with the IPD process (Figure 2-4), ITT A/CD fully involves its Business, Engineering, Operations, Finance, and Contracts departments up front at the bid and proposal stages. The company then simplified its Business Development Process to focus on key standardized management tools (e.g., Integrated Management Plan, Capture Plan, Proposal Plan) that are available electronically. Charts, checklists, and templates are also maintained for each tool in a Capture Team/Proposal Team Notebook. Business area directors and product line steering teams are now included in the review cycle, and the price/cost review was moved forward to Milestone 2A (on the flowchart) to allow more time to work these issues. Support for the tools and procedures is a key factor to successfully implement this process. ITT A/CD relies on its trained process coaches and product experts. The process can also be tailored and applied to every product development project.

By using the management tools, the business development team integrates each member's input to facilitate communication and decision making. The tools also help the team identify whether a project is winnable, within the capabilities of the company, worthwhile to pursue, as well as what to do once a contract is awarded. Many front-end concept development and architecture tasks are completed prior to the start of the project. This shifts much of the cost to the front end of the project. ITT A/CD now expends one-fifth to one-third of the total project budget at the

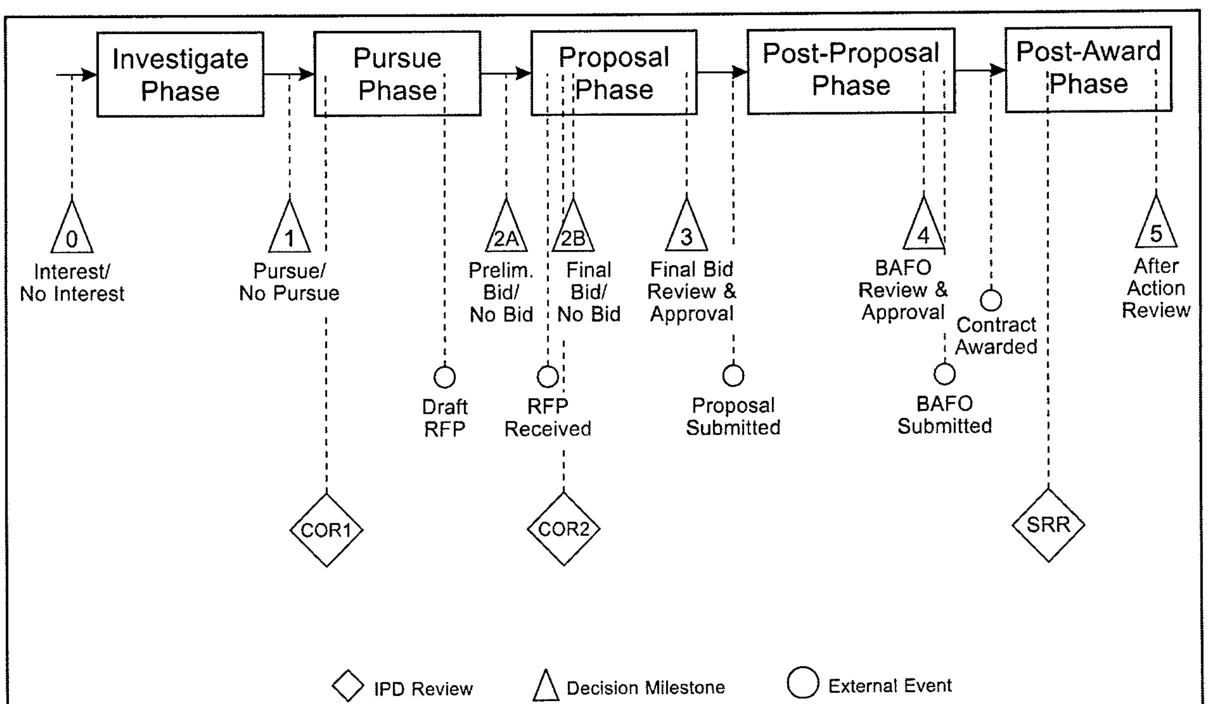

Figure 2-4. Key Business and Integrated Product Development Milestones

bid and proposal stages. The company discovered that this is money well spent due to the high win rate of nearly 80%. The up-front emphasis ensures that all the ground work and planning are completed, so work on the project can begin immediately upon contract award.

ITT A/CD's Business Development Process provides an earlier and more effective allocation of program resources which results in a more solid program plan, smoother program start-up, earlier cost versus price strategy, and earlier completion of necessary forms and approvals. In addition, the program plan, design, win strategy, cost rough order of magnitude, and team are established very early on, allowing adequate time to execute an orderly proposal approach and to work cost issues. As a result, ITT A/CD can immediately begin work upon contract award, rather than spend time planning its approach.

Common Process Management Council

In 1995, ITT A/CD and DCMC formed the Common Process Management Council (CPMC) as a joint contractor/customer management team. The council's initial responsibility was to facilitate the Department of Defense's Process Oriented Contract Administration Services (PROCAS) Initiative. Prior to the CPMC, no formal contractor/customer mechanism existed to address problems, resolve issues, or facilitate improvement initiatives.

The CPMC consists of senior management staff from ITT A/CD and government (e.g., DCMC, NASA, NSA) who meet monthly at ITT A/CD. The council provides support for the Commercialization and Acquisition Reform Initiative; charters and facilitates PROCAS teams; reviews and approves submission of Single Process Initiatives and block-change requests; assigns resources; and reviews status on process improvements. In addition, the CPMC addresses problems and resolves issues that are brought to the council. One of the process improvements overseen by the CPMC was the No-Clean, Low-Residue Soldering process. Once implemented, this process reduced volatile organic emissions and hazardous waste generation, improved cycle time, and resulted in a savings of $700,000 per year.

The CPMC provides many benefits to ITT A/CD and the government customers. Among these are improved communications between contractor and customer representatives; consensus priorities for improvement initiatives; pooled resources for working on new initiatives; and significant savings and achievements from PROCAS efforts and Single Process Initiatives.

Earned Value Management System

In a cooperative effort with various government agencies, ITT A/CD developed and implemented the Earned Value Management System (EVMS). This management control system is used for current and future Research Development Test and Engineering and production contracts that are valued at more than $500,000. Previously, ITT A/CD relied on traditional cost and schedule analysis systems such as cost schedule status reports or cost performance reports.

ITT A/CD's cost account managers are responsible for determining the technical schedule and budget performances, and establishing the initial performance measurement baseline. EVMS provides managers with the tools to collect, accumulate, and compare actual cost, schedule, and technical performances against a plan. Based on the data, the managers can make decisions that deliver the best value to the customer. Unlike most cost and schedule analysis systems, EVMS provides an objective measure of how much work has been accomplished based on the planned value of work for a specific time period. The system also measures program accomplishments as well as resources used. Managers conduct earned value performance measurements each month, and generate new program completion dates every three to six months.

As a result of implementing EVMS, ITT A/CD now has a universal system approved by all customers which links its schedule and cost reporting systems. In addition, EVMS provides flexible formats for standard computer tools; generates data quickly; controls the level of effort activity through time phased budgets; and handles internal and customer tracking.

Integrated Management Plan

ITT A/CD developed and implemented a disciplined and comprehensive planning tool called Integrated Management Plan (IMP) to communicate, coordinate, and document all elements of a program from concept to completion. The IMP process has been in effect for nearly three years, and the company has applied this process to approximately 80% of its programs. Prior to IMP, planning was either performed late in a program's life cycle or on an inconsistent basis. A series of disjointed plans was usually done by different organizations without any effective coordination. ITT A/CD needed a process to deal with the increasingly larger numbers of program starts; provide a single program plan that had buy-in from all

disciplines; and facilitate senior staff commitment to all integrated plans.

The IMP process begins by assembling a core team that communicates with senior staff and the customer product line team to clearly understand the goals of the program. The core team works together to understand and interpret these objectives, and collaborates with key task leaders and experts to plan how they will implement the program. The plan is then clearly documented in the IMP process. This step is the most difficult but crucial part of the process, because it eliminates any misunderstanding resulting from a trickle-down flow of information and hand-offs within the organization. Next, the core team uses the IMP process to obtain the concurrence of the key task leaders and senior staff. The IMP process becomes the core team's implementation plan and contract with senior staff for launching the program. In addition, the process provides the framework that allows work to begin immediately upon contract award, and to proceed well within the cost and schedule constraints.

Key elements of the IMP process include: program overview; key assumptions; inter-program crossfeeds and dependencies; performance characteristics; team deliverables; tailored design process; top-level schedule; financials; risk register; operations approach; preliminary project plans; staffing; contracts; and customer involvement. The core team as well as each organization provide appropriate inputs to the IMP process. ITT A/CD is currently improving its process by streamlining the format, and automating the process on the company's electronic data management system.

ITT A/CD's IMP process provides a smoother transition for new team members and a better understanding of tailoring requirements by functional managers. The common goals and structure of the process produce team harmony, while the disciplined approach helps eliminate the temptation to start work before the planning phase is completed. The IMP process is successful because the process is simplified, superceded requirements are eliminated, and functional managers concur with the plan.

Program Launch Process

In the first quarter of 1997, ITT A/CD was faced with starting 15 new programs. Previously when a contract was awarded, the departments would scramble to get resources; define budgets and schedules; and haphazardly start production. Departments tended to work independently with little coordination among themselves. With limited advanced planning and no formalized process, the introduction of new programs often lacked well-executable steps, dedicated resources, adequate funding, program objectives, and launch schedules. As a result, new program launches were unsuccessful, resulting in false starts, low yield rates, high defect rates, missed schedules, excessive costs, and interruptions in new and existing production. In 1997, ITT A/CD established the Program Launch process as an organized method to ensure that budgets, schedules, resources, equipment, facilities, and materials required for launching new programs are identified, planned, and implemented prior to production.

Upon contract award, the Program Launch process begins. The steps include assembling a core team of senior staff; interpreting the contract and plan; identifying key task leaders and training requirements; reviewing the technical baseline; updating the IMP process; collaborating with senior staff and directors; establishing baseline/detailed schedules and budgets; identifying additional needs; and implementing the program. A program start-up checklist itemizes each action item, responsible member, plan date, and status. Approximately 80 people have received more than 20 hours of IPD training consisting of an overview, program launch procedures, effective meetings, a Microsoft Project video, electronic data management system accessibility, and other development tools as required (e.g., quality function deployment; requirements traceability and management; failure modes and effects analysis; decision making; risk management).

The core team's creed is to talk, think, collaborate, plan, document, concur, and launch:

- Talk to the customer product line team and senior staff to clearly understand the goals of the program.
- Think and interpret these objectives.
- Collaborate with key task leaders and experts.
- Plan how to implement the program.
- Document the program clearly by using the IMP process to avoid misunderstandings due to trickle-down information and hand-offs.
- Concur with key task leaders and senior staff.
- Launch the program by using the IMP process as the core team's implementation plan and contract with senior staff.

ITT A/CD's Program Launch process provides a smoother method to launch new programs. Currently, the company's baseline launch period for a new program is 65 days, with a goal set for 60 days.

Success relies on assembling a staff early, providing forecast training, establishing plans before starting work, and updating requirement documents.

Risk Management Process

In the past, ITT A/CD only used risk management in preparation for production transitions. This was an intermittent practice which focused on reactive solutions to problems. However, the demand for quicker development times for its commercial satellite deliveries motivated ITT A/CD to establish a risk mitigation tracking tool. In 1994, the company set up a formal Risk Management process to identify and eliminate potential problems before they can impact the completion of a program.

ITT A/CD's Risk Management process works as an integral part of the Product Development process, and evaluates all facets of risk items (e.g., hardware, software, programmatic components). Program personnel identify how risk will be measured, and define the major risk decision points in the program's process. A key feature of the Risk Management process is assessing program issues that the customer considers absolutely necessary. Known as cardinal points, these issues are collectively viewed by ITT A/CD and the customer, and are addressed through concerted efforts. Key program personnel then evaluate the program's objectives and cardinal points, and assign a risk factor to each. The risks are then prioritized, and the top 25 risks are incorporated into a Risk Mitigation Strategy. Since this strategy is also part of the Program Management process, the company gains a global view of the program by addressing risks early. The Risk Management process helps to clearly delineate the interrelationship of the program's components for the staff, and allows the customer and program managers to be involved in decisions up front. Figure 2-5 shows the flowchart of the Risk Management process.

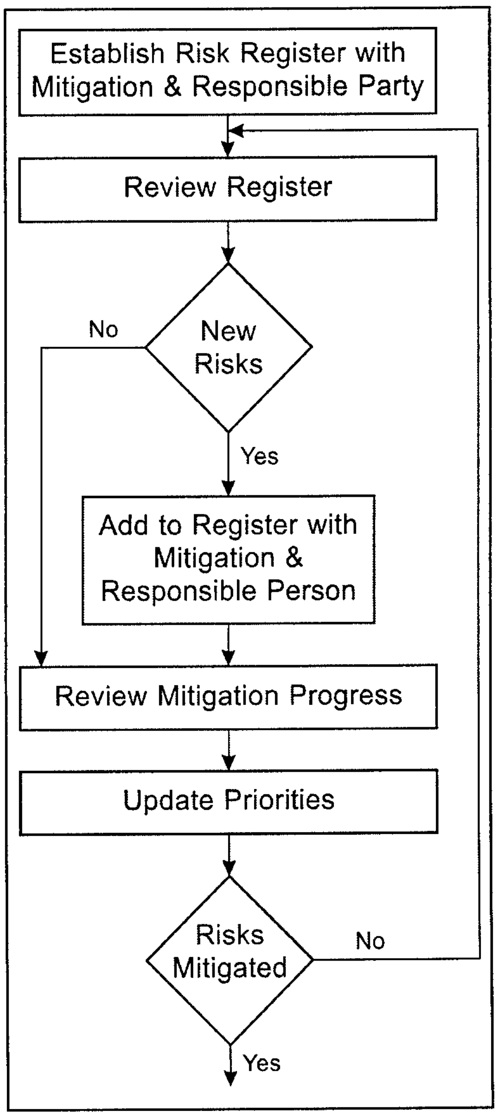

Figure 2-5. Risk Management

ITT A/CD's Risk Management process addresses risk items early in the Program Development process. This approach provides objective decisions on mitigation plans; enables the highest impact issues to receive attention first; prioritizes the assignment of resources; keeps the customer and program management focused on the cardinal points; and works as a proactive process. As a result, ITT A/CD now accomplishes its commercial satellite deliveries in half the time and under budget.

Technology Roadmap

Prior to 1992, ITT A/CD's Operations Engineering department had no formal method to track its needs for programs relative to the Manufacturing for Design (MFD) initiative. Instead, the department relied on reactive practices to handle opportunities and preparations (e.g., capital budgets, independent research & development (IR&D) budgets) of the new programs being released for manufacture. Strategic planning was limited to a one-year period, and had minimal interaction with the design, systems, and business development aspects of programs and the overall company. ITT A/CD lost many opportunities for long-term advantages, and often failed to meet its customers' needs. Decisions were based on feelings and personalities rather than business requirements. As a result, short-term solutions could not satisfy long-term requirements or accelerated product development cycle times. In 1992, Operations Engineering introduced the Technology Roadmap as a vehicle for tracking technology trends, requirements, and execution.

The Technology Roadmap is an integrated master plan to track the critical manufacturing and test technology needs for current and future programs relative to the MFD initiative. Updated and maintained in real time, the roadmap documents where technology is going relative to business requirements for a three- to five-year period. This data-driven tool captures and charts internal and external technology trends through numerous sources such as surveys, literature searches, benchmarking, conferences, and the Internet. The Technology Roadmap also tracks requirements by customer, business development, strategic planning, program management, and engineering needs as well as addresses technology execution and implementation; next-generation products and processes; and feedback. As a living document, the roadmap easily communicates technology trends, needs, and progresses of ITT A/CD's programs, and serves as a vehicle to share technologies among the company's avionics, aerospace, and communications divisions. This approach helps avoid duplication of capabilities and typically provides solutions for hard-to-solve manufacturing problems.

Operations Engineering's Technology Roadmap is an essential tool for planning, budgeting, and implementing the company's next generation processes at the right time and at the best value. Since implementing this tool, Operations Engineering makes better decisions on which technologies to pursue and stronger justifications for budgeting capital improvements and IR&D projects. The Technology Roadmap also provides the basis for improved coordination between ITT Avionics (New Jersey) and ITT A/CD, resulting in the exchange of surplus capital equipment and the coordination of long term capital procurement.

Video Production Facility

Previously, ITT A/CD's video capabilities consisted of a single video camera and two reel-to-reel video recorders. Since in-house editing capability was minimal, the company spent $2,000 per day for an outside vendor to provide final editing, titles, captions, and graphics. However, reliance on an outside vendor began impeding ITT A/CD's schedule deadlines and tight departmental budgets. In 1995, the company invested in a state-of-the-art Video Production Facility to handle all aspects of video production. Today, the facility produces quality training and commercial videos for internal and external customers.

The video production process starts with a preliminary concept discussion with the customer. From this, the storyboard concept is developed, and the appropriate scripts, actors, stills, graphics, and audio needs are assembled. ITT A/CD can film the video material either in a studio or on location. Once filming is completed, the sound tracks and graphics/animation are added. Then, the video is reviewed by the customer, shown to a test audience, finalized, and copied for distribution. The new production system is fully digital and produces high resolution, top quality videos. In addition, the new equipment and software are fully compatible with the company's existing equipment in the Graphics and Electronic Publishing departments.

By establishing the Video Production Facility, ITT A/CD controls the entire production process for its training and commercial videos, and eliminates the need for outside vendors. In addition, the company decreased its turnaround time for a finished product by more than 60%. The Video Production Facility has been very successful in producing premium videos for ITT A/CD and its customers, and won numerous commercial and film awards. Among these are the Telly Awards in 1996 and 1997; the Crystal Communicator Award in 1997; a gold medal in the International Cindys in 1998; and the John Cleese Comedy Award in 1998.

Section 3

Information

Design

Design Review Manual

ITT A/CD's Design Engineering Group recently updated its design review process by implementing an automated, on-line version of the Design Review Manual. The previous practice was driven by customer requirements; lacked a defined objective; varied depending on the initiator; and relied on intermittently conducted design reviews. In addition, employees endured bulky documentation that was often misplaced and quickly became outdated after publication.

Accessible on ITT A/CD's Intranet, the Design Review Manual offers improved design quality, lowers overall product cost, shortens cycle times, and provides guidance for inexperienced design engineers. By automating this manual, ITT A/CD eliminated bulky documentation, increased employee participation, and provided users with a real-time review of current design requirements. Other benefits include consistent expectations and defined objectives; higher quality products from a more comprehensive design review; independent chairpersons for the design reviews; measurable metrics that ensure compliance to the design process; and quicker design concurrence between the Engineering Management and IPD teams.

Design-to-Cost Reduction Planning

In the past, ITT A/CD determined unit costs after production rather than as part of the design phase. Design engineers focused on performance and paid minimal attention to recurring unit production costs. As a result, the necessary cost reduction efforts became a post design release process driven by senior management who instituted reductions to remain competitive. Cost reductions also involved suppliers and operations, and often resulted in hardware elements being redesigned to accommodate a lower cost approach.

ITT A/CD revised its practices, and established Design-to-Cost (DTC) Reduction Planning to meet changing customer contract objectives and to compete more aggressively. The company consolidated the disjointed sections of its previous practices into a structured system. ITT A/CD also established objectives to meet contract-mandated, unit-cost reduction quotas, and used measurements to evaluate the IPD output of the process. The DTC system integrates all elements of the design and manufacturing processes. First, management establishes competitive cost targets. Next, the bill of materials and all manufacturing information are loaded into the material requirements planning system. Labor estimates are then calculated, and advanced manufacturing and test engineering personnel work with suppliers to cost any custom requirements. A first draft of the design-to-unit production cost is established, and then the design and manufacturing processes are reviewed again for completeness and data validation. The unit cost is baselined, and management compares this cost to the cost target. In addition, management identifies any additional cost considerations. The unit cost is then updated with quotes and all factory, assembly, and test operations information for a second draft. The final unit cost is negotiated with the customer.

DTC Reduction Planning enabled ITT A/CD to compete more aggressively, resulting in contract awards for entire production lots. The system provides objective measurements of IPD outputs; fosters organizational culture change; and promotes innovative thinking. The process is now embedded in all programs which require production hardware, including low volume projects. ITT A/CD exceeded its cost targets which resulted in a unit price reduction of 75% between 1989 and 1998.

End-to-End Modeling

Weather satellites use imagers (Figure 3-1) to provide geostationary imaging data such as cloud tracking, sea surface temperature, and atmospheric changes. The satellite directs the imager's line of sight by rotating its scanning mirror; however, the mirror must stay optically flat within 50 millionths of an inch to keep the imager in focus. For all precision mirror designs, the goal is to create a mirror with minimal optical distortion by selecting the proper thermal, structural, and optical models. Previously, ITT A/CD would generate (independent of one another) thermal models to predict orbital temperatures, and structural models to predict strength and structural frequencies. The optical model was then determined by using optical codes and manually-calculated, worst-case distortion estimates. As a result, verification testing was expensive and could only

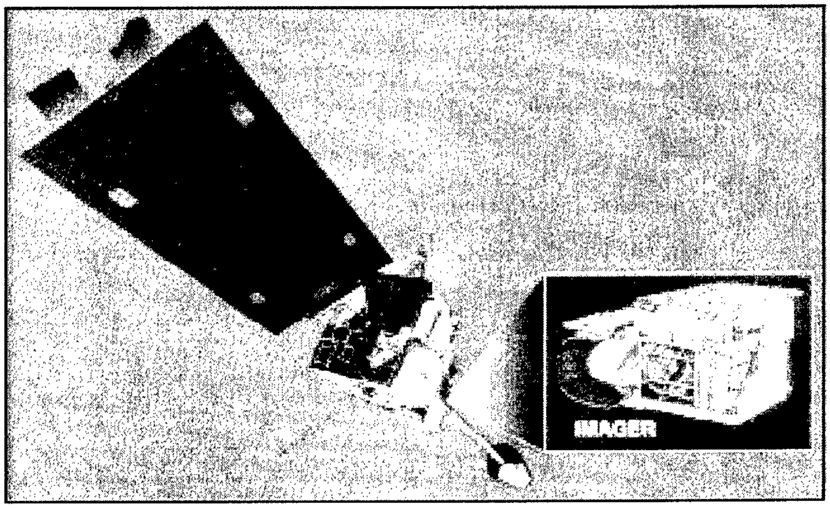

Figure 3-1. Geostationary Operational Environmental Satellite with Imager

be performed on flight-like hardware. ITT A/CD needed an analytical method that could allow the engineers to evaluate numerous design alternatives.

ITT A/CD developed End-to-End Modeling to perform design analyses on complex product development projects such as minimizing the distortion of geostationary scanning mirrors. These efforts were directed at the Geostationary Operational Environmental Satellite (GOES) and the Satellite-Based Infrared System (SBIRS) programs. In mirror design analyses, the engineer first simulates a thermal model and uses its results (analytical predictions) as input for simulating a structural model. These results (distorted mirror shapes) are, in turn, used as input for simulating an optical model. The final results (system performance) help the engineer determine an optimum mirror design. End-to-End Modeling automatically inputs the results of each model's simulation into the next simulation, allowing the engineer to evaluate numerous design alternatives. This approach also helps the engineer assess conflicting design tradeoffs (e.g., cost, schedules, technology risks, mass, volume, material properties).

End-to-End Modeling promotes a design-of-experiments approach using Taguchi methods to identify key structural aspects that minimize mirror distortion. In addition, the assessments from this modeling enable ITT A/CD to verify that the optical system is performing according to the customer's requirements. In the latest upgrade for the GOES program, the scanning mirror's distortion was reduced by a factor of three, which translates optically to a factor of nine. In the SBIRS program, the scanning mirror's distortion was reduced by a factor of two, and the structural stiffness was increased by a factor of two.

Peer Review

ITT A/CD's Design Engineering instituted Peer Review as an initiative for design evaluations. This initiative established a documented, informal, design review process. Previously, no documented process existed. Although informal reviews were performed individually by default on smaller programs, larger programs had difficulty with technical coordination and implementation. In these cases, designs tended to be disjointed, minimal operational department involvement which led to a lack of available support during the production phase.

The requirement for Peer Reviews is delineated in the Design Review Manual. Design engineers invite operations experts and experienced engineers from various departments to attend informal presentations and evaluate their proposed designs. Peer Review allows the efficiencies obtained from smaller programs to be projected into larger programs through closer technical coordination with other operational departments. This teaming effort has improved the design quality at ITT A/CD by promoting communication between the Electrical, Mechanical, and Design Engineering departments, yet still maintains its focus on the customer's requirements and satisfaction. In addition, Peer Review acts as a mentoring vehicle so inexperienced design engineers can gain insight from experts in attendance. Overall, ITT A/CD gains the best technical approach to designing by achieving concurrence from all departments and by conducting cross-functional training of design review attendees.

Rapid Prototyping

ITT A/CD developed Rapid Prototyping to shorten its mechanical design/development cycle time and to improve the success of first-article environmental tests. This process uses an electronic suite of software tools to quickly produce a prototype, which provides the engineer with additional time to consider tradeoffs and alternative evaluations. The result is a higher quality final product. Early mechanical prototypes also enhance producibility by reducing fabrication costs and assembly problems through early detection, and by increasing manufacturing feedback to resolve issues prior to production release. Previously, a draw-

ing/sketch had to be produced before a part could be machined. The machining house then interpreted the drawing/sketch which increased the chance of translation errors occurring. In addition, design issues were often not discovered until the first-article part was produced, resulting in expensive redesigns. ITT A/CD needed a new process that identified issues early in the design process, eliminated interpretation errors, and performed fit checks (tests) prior to the release of final drawings.

ITT A/CD created Rapid Prototyping utilizing state-of-the-art, integrated mechanical CAD/CAM systems and processes (including 3-D solids modeling using Pro/ENGINEER and Pro/MANUFACTURE software) to allow direct use of the design database by modelshop and manufacturing personnel as well as outside suppliers. Pro/ENGINEER enables fit checks to be performed prior to the release of final drawings, accounting for most real-world situations. After entering a design into Pro/ENGINEER, the engineer can electronically transfer it into Pro/MANUFACTURE where a target file is produced for the target modelshop process. Metal parts can be produced in one to three days if testing is needed, and Stereolithography parts can be produced in three to five days if fit checking is needed. The electronic suite of tools provides software compatibility and integration:

- Concept uses Pro/ENGINEER
- Drawing (if required) uses Pro/DRAFT
- Fabrication uses Pro/MANUFACTURE
- Analysis (if required) uses Pro/MESH
- Electrical (if required) uses Pro/ECAD
- Inspection uses Pro/CMM (available soon) or CAV

Rapid Prototyping provides ITT A/CD with a paperless process to reduce design/development cycle times and successfully produce first-article parts. The 3-D electronic representations result in higher quality designs, lower design costs, improved customer confidence, and more successful first-time assembly of products. The company identifies design issues earlier which reduces expensive redesigns. Rapid Prototyping's compatible suite of tools eliminates translation errors, promotes design control, provides quicker design turnaround, and eliminates the need for drawings.

Robust System Design Process

Previously, ITT A/CD's design process was a nine-step method which relied on concurrent engineering and IPD97. As designs grew in complexity along with the need to define specific critical tolerances, this process became too costly, continuously exceeded projected cycle times, and lacked strong communication tools. To resolve this situation, ITT A/CD developed a Robust System Design process which lowered design costs and reduced IPD cycle times. Robust refers to designs that perform in the customers' environments according to their expectations.

The Robust System Design process is a total life cycle approach that uses a series of methods and techniques which complement the design process. These methods and techniques are well established reliability design tools used throughout industry — quality function deployment; structured analysis; fault analysis; parameter design; modeling and simulation; technical performance measurements; risk; requirements management; and design reviews. These tools help design engineers identify needs and address critical factors (e.g., complexity, cost restraints, reliability risks, tolerances) during the design stages of the product. ITT A/CD provides training in all these tools so design engineers can develop their skills and establish a reliable design base. Inexperienced engineers receive additional help from mentors who help them identify the tools of choice for their individual projects.

The tools used in the Robust System Design process enable design engineers to collect detailed information early in the concept phase. This data is documented for individual parts and project requests. In addition, the Robust System Design process supports commercial part usage, and its process philosophy is applicable to various projects. Since implementing this process, ITT A/CD reduced its production costs by one-third.

Technical Performance Measures

In the past, system and design engineers tried to control all specification parameters of a product with equal effort and priority. Since this strategy lacked performance tracking tools, engineers struggled to identify cardinal items that controlled performance, and typically lost sight of the system's overall balance. ITT A/CD developed Technical Performance Measures (TPMs) as a rational way to assure ultimate system performance, quality, and customer satisfaction. TPMs are the key technical requirements of a system, subsystem, or component that are critical to meeting the customer's objectives of a product.

TPMs consist of metrics (e.g., expected value, allowed margins, parameter variations over time) which are developed from requirement prioritization; program experience; and quality function deployment, a method of helping IPTs focus on critical customer

wants and needs. TPMs are generated by identifying these critical parameters. In addition, modeling, analysis, estimation, and/or measurement are used to determine each critical parameter's performance value. Since data trends are an important aspect, TPMs are tracked as a function of time (e.g., monthly) throughout a product's development cycle which allows the engineer to analyze trends and take appropriate actions.

ITT A/CD uses TPMs on all its programs which has resulted in joint customer, management, and project visibility regarding the technical performance of a product's development activity, both current and historical. TPMs allow early detection and prediction of problems; represent an important part of the margin management process; and are used to monitor key technical assumptions and directions.

Test

Automated Test Equipment Review and Validation

Previously, independent functional organizations at ITT A/CD sequentially carried out product test requirements; test hardware and software development; and quality/customer validation of automated test equipment (ATE) with little interaction or mutual input. This approach led to long development times, interpretation errors, unnecessary costs, and some final products with incomplete testing. ITT A/CD developed the ATE Review and Validation process based on the IPD team approach and use of peer reviews.

The IPD team consists of representatives from all pertinent functional organizations (e.g., design, test, quality, production, customer). The team meets regularly during the entire design process, ensuring that all members are heard during the development phase and agree with the end results. At the conclusion of the ATE design phase and prior to the ATE build phase, an Initial Peer Review is held which involves the test project leader, design engineer, and test support engineer. This group reviews the ATE design including product specification, proposed ATE drawings, test methodology, and test data storage. Action items are then assigned, and must be completed before the ATE build phase can proceed. At the conclusion of the ATE build phase and prior to the ATE quality/customer validation phase, a Final Peer Review is held which involves the Initial Peer Review members plus quality and customer representatives. This group reviews the ATE design including actual test methodology and required maintenance, and ensures that the quality and customer representatives understand how the ATE meets the product specification. Action items are then assigned, and must be completed before the ATE quality/customer validation phase can proceed.

Since implementing the ATE Review and Validation process, ITT A//CD has increased communication and mutual understanding among its functional organizations; reduced debugging time; created a robust, standardized design procedure; and ensured all tests are performed. In addition, validation time has been reduced from two weeks to two days.

Field Feedback

After the first major fielding of SINCGARS in Korea, ITT A/CD realized it needed a Field Feedback program. Obstacles included the lack of reliable field contacts; no reliable means of communicating field problems between the customer and ITT A/CD; problem areas were not being properly addressed; and the customer was losing confidence in the product's field performance as well as follow-on support.

In response, ITT A/CD sent a team of manufacturing, reliability, logistics, and management personnel to the field site to address these problems and restore customer confidence. The team set about designing a long-term/permanent vehicle for handling the exchange of information between ITT A/CD and the field site. Also implemented was an on-site field service representative (FSR) who addressed open and closed maintenance actions; discussed equipment problems; and supplied configuration information on the number of units serviced at the field site. These communication channels enabled ITT A/CD to identify trends, patterns, and/or repetitive failures in the equipment; supply valuable information on the quality and accuracy of the equipment; and determine whether user technical training or technical support was needed.

In addition, ITT A/CD established an Internet website so customers and FSRs could report real-time failures and customer inquiries. This avenue of notification enables ITT A/CD to immediately launch investigations via Product Quality Deficiency Reports and begin corrective action procedures.

Production Reliability Acceptance Testing

ITT A/CD uses Production Reliability Acceptance Testing (PRAT) to demonstrate successful subsystem operation in simulated field environments, and to verify compliance with contractual reliability re-

quirements. This aggressive testing also confirms consistency in the product's manufacturing processes, and identifies changes in the component's quality or supplier's manufacturing processes.

Sample functional testing is performed quarterly on 12 vehicular long-range configurations for a total of 15,560 test hours under controlled environments (e.g., thermal excursions, vibration, power cycling, voltage cycling, moisture injection). Over a nine-year period, ITT A/CD conducted 49 PRATs, accumulating more than 766,255 total test hours. For its latest equipment design iteration, ITT A/CD determined the product's Mean Time Between Failures (MTBF) at 5,399 hours. This result is four times better than the failure rate (1,250 hours MTBF) required by the program. PRAT's aggressive approach was a predominant factor in the company winning two production year (PY11 and PY12), sole-source contracts.

In conjunction with this test philosophy, ITT A/CD also uses accelerated Test, Analyze, and Fix (TAAF) product analysis. Although performed at an accelerated rate, TAAF is a mirror image of the testing profiles used for PRAT, and its associated failure rates are based on the PRAT profiles observed. ITT A/CD conducts TAAF on equipment to promote reliability growth and identify areas for improvement within the current design. TAAF also identifies the operational limitations under which the equipment will work, which provides the company with a better assessment of design margins and a timely feedback of design, manufacturing process, test, and/or supplier shortcomings.

Production

Chemical Reduction Program

Prior to 1991, ITT A/CD lacked hazardous chemical reduction goals, and had no formal review team to monitor the chemicals being used in its manufacturing process. At that time also, government mandates regarding hazardous chemicals were being formulated throughout the United States. Awareness of these chemicals and their health risk to employees began to grow at ITT A/CD. In 1991, the company initiated a Chemical Reduction program and set up a Chemical Review Board.

The Chemical Review Board establishes the chemical reduction goals at ITT A/CD. In conjunction with the Board, a multi-functional team evaluates the chemicals used in the manufacturing process based on toxicity, regulatory status, and quantity. This team is also responsible for implementing the Board's reduction goals. Quarterly reports are then generated by the Board, and sent to ITT A/CD's local officials and corporate management. In addition, the Chemical Review Board posts all accomplishments and decisions regarding the program on the company's Intranet for employees to view.

ITT A/CD significantly reduced its hazardous chemicals between 1990 and March 1998 (Figure 3-2). Over the last four years, the company achieved a reduction rate of 5% to 15% per year. Since implementing its Chemical Reduction program, ITT A/CD decreased its conformal coating usage by more than 50%; achieved substantial savings by switching to a no-clean flux for its flow soldering process (a cooperative effort between ITT A/CD and its government customers); and established a cleaner, healthier environment for its employees and community.

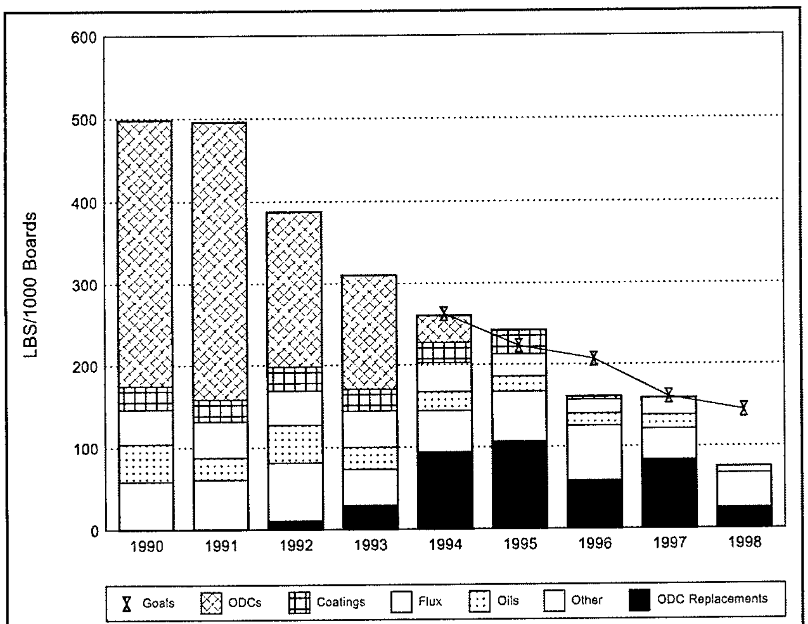

Figure 3-2. Hazardous Chemicals Reduced

Defect Analysis Team

Several years ago, the Circuit Card Assembly area experienced recurring defects. In response, ITT A/CD established the Defect Analysis Team (DAT) as a

governing body to assure in-circuit yield improvements. This cross-functional team consists of production, manufacturing, and quality engineering personnel.

DAT set up a four-level defect pareto analysis based on in-circuit yields: Level One is In-Circuit Yield History, consisting of all boards; Level Two is In-Circuit Defect Trends, broken down by assemblies, components, solder, and miscellaneous; Level Three is a break-down of each level two attribute; and Level Four is a listing of all defects. DAT Root Cause Corrective Actions are based on the worst yielding assemblies according to the defect pareto analysis.

Through DAT's efforts, ITT A/CD established or changed several processes which reduced the number of defects. This approach is an important tool used by the company in reaching its goal of first-time test yield improvements.

Failure Reporting, Analysis, and Corrective Action System

Previously, ITT A/CD used a labor-intensive system for handling failures, analyses, and corrective actions of units. Documentation consisted of paper travelers for unit configurations; log sheets for test failures; and failure report and analysis forms for failure causes. This information was then compiled and manually entered into a database. Reliability personnel used this database to perform reliability trend analyses, identify critical failures, and develop corrective actions. In addition, the Failure Review Board manually tracked pattern failures and corrective actions. This time-consuming system lacked flexibility, was difficult to control, offered no relationship between configuration histories and failure reports, and failed to keep up with production increases. ITT A/CD resolved this situation by developing the Failure Reporting, Analysis, and Corrective Action System (FRACAS).

FRACAS is an automated system. Unit configurations are now entered into the computer system by scanning a barcode, and valid part numbers are loaded by reference designator from released parts list. Since test stands are tied into the system, all failures will automatically cause a failure report to be generated. If an open reject exists on a unit, the next automated test cannot be performed. In addition, the final test program will flag any missed tests. Reliability personnel use FRACAS' database and programs to automatically generate trend information and failure percentage rates.

Since implementing FRACAS, ITT A/CD reduced its data entry and analysis time from several weeks to a few seconds. In addition, the company eliminated the need for manual data entry; established a relationship between configuration histories and failure reports; and can capture accurate failure history data.

Failure Reporting, Analysis, and Corrective Action System for Electro Optical Space Projects

ITT A/CD developed the FRACAS for Electro Optical Space Projects as a means of documenting, analyzing, tracking, and resolving incidents that occur on space projects. This dynamic system provides the company with flexibility to perform efficient failure reporting, disposition, and closure.

The process begins with an incident (e.g., out of specification condition, system failure) which any employee can document by manually recording it on a pre-numbered incident report (IR) form. ITT A/CD chose this method to ensure that immediate documentation could not be hindered by a computer failure. The flight hardware risk is assessed, and a floor disposition allows testing to continue to minimize test downtime. The information on the IR is typically entered into a computer database within 24 hours of the incident. ITT A/CD troubleshoots each incident to determine its root cause (e.g., instrument performance, software, test equipment, setup, human error), determines the corrective action, and then closes out the IR. Depending on the results, a retest or rebuild may be required.

The FRACAS for Electro Optical Space Projects provides ITT A/CD with various tracking information and trend data. Among these are open IRs, MTBF, cycle times, test phases, incident sources, second-tier analysis, and corrective actions. Since implementing this system, ITT A/CD reduced its GOES incidents from 803 (unit SN03) to 168 (unit SN07). Trend data is often used by the company to determine process improvements, reduce cost on existing projects, and bid on new projects.

Filter Housing Process Development

ITT A/CD established a state-of-the art model/machine shop which can produce very small tolerance products. Equipped with computer numerically controlled machining capabilities and automated process generation and verification, this facility is also used for short turnaround and unique build requirements.

ITT A/CD's previous process for producing a filter housing was labor intensive, and required numerous manual operations. Operators performed machine programming by generating paper tapes, and many calculations were performed by hand. Machining processes involved multiple tooling steps that required a part to travel from tool station to tool station. In addition, most jobs required secondary operations; troubleshooting was difficult; and machining errors occurred frequently.

After winning a new project, ITT A/CD decided to update and streamline its process. Changes included reducing schedules, minimizing costs, limiting non-recurring engineering, tightening tolerances, and establishing design guidelines. The company also developed dimensioning schemes to standardize tolerances and critical dimensions. Programming techniques were now performed via commercial software packages (e.g., Pro/ENGINEER, Pro/MANUFACTURING, Vericut, Interleave) when entering machining parameters into the system. ITT A/CD reduced cycle time by minimizing its processing techniques and establishing cluster towers, which consolidated tooling into one tool station. By connecting all machining equipment to a common Intranet, operators can easily access all machining information.

Since implementing these improvements, ITT A/CD reduced the cost of producing a filter housing from $1,934 to $736. This significant saving helps the company remain competitive.

Fully Automated Testing

ITT A/CD wanted a method that would reduce test manpower but improve efficiency, decrease cost, and meet production increases. However, only so much manpower can be eliminated through sample testing or test elimination before potential product issues arise. The company examined potential techniques (e.g., improving test execution, test flow, yields, troubleshooting efficiency), and chose automated testing as the primary method to reduce manpower.

Automated testing (operator independent testing) has existed at ITT A/CD within the SINCGARS program. The original concept used an XY table and a Z-axis arm to perform numerous test operations on the radio. This method was slow, and the Z-axis arm could not reliably do all test operations. No incentive existed for test personnel to improve the method. However, the winning of a new radio contract resulted in ITT A/CD developing a simpler radio. Automated testing is now more feasible, and the company reduced its test times from 112 minutes to 45 minutes, meeting the contract's test time targets.

ITT A/CD has designed an automated test cell that will significantly reduce manpower. The test cell's process sequence includes:

- The operator manually loads each radio into a tray, does a pre-test inspection, and places the radio's switch in the home position.
- At the pre-test and scanning station, the system verifies that each radio is properly positioned on the tray and that the knob is in the correct location. The system then scans the barcode information and interprets what tests are needed.
- The radios are transported on conveyors to various automated test stations.
- As the radios leave the test stations, the system decides whether the unit is sent to the thermal chamber, the air seal test, or the repair conveyor.

Potential savings from automated testing include a manpower reduction of 15 to six across three shifts; faster cycle times with continuously-run operations; decrease in operator error; and lower maintenance costs. ITT A/CD estimates that the system will save the company $2 million over a three-year period.

Manufacturing Confidence Evaluation

ITT A/CD developed the Manufacturing Confidence Evaluation (MCE) process as a way to tailor manufacturing screens used during production. This approach obtains the greatest benefit for a level of expenditure, and precipitates workmanship and manufacturing defects as early as practical in the production cycle. Previously, ITT A/CD used a non-tailored, contractually-required Environmental Stress Screening (ESS) process within its production cycle. The company performed this standardized process at three manufacturing levels: Level A (board level); Level B (module level); and Level C (finished unit level). Despite running a three-level ESS, ITT A/CD still found manufacturing defects present at the highest level, which indicated ESS (as specified by the contract) was not effectively precipitating enough defects.

MCE is a highly-tailored version of ESS. The process is driven by specific hardware needs and product/process maturity, and seeks buy-in from the customer. In developing MCE, ITT A/CD used quality methods (e.g., Taguchi design-of-experiments) to determine the most effective number of cycles and temperature ranges for thermal shock testing. An ESS Level A profile consists of 20 thermal shock cycles, unpowered, five minute dwell, and a -75°C to 85°C range. After extensive analysis, ITT A/CD modified the profile's parameters to 15 thermal shock cycles, five minute dwell, and a -58°C to 103°C range,

which precipitated more defects at Level A. By identifying defects at this lowest level, ITT A/CD realized an average loss reduction of $7.30 per circuit card assembly — a significant reduction considering the high production quantity of these assemblies.

Through analysis, ITT A/CD also determined that Level B provided no additional value once Level A profile was tailored. This step was progressively eliminated as each module yield improved. As a result, the cycle time of modules decreased by more than 14 hours without adversely affecting end-item reliability and quality. A similar analysis reduced Level C's cycle time by 16.5 hours on the receiver/transmitter and 30.7 hours for each vehicular applique.

By using the MCE process, ITT A/CD significantly reduced its cycle times and tailored ESS within the company's production effort to receive the greatest benefit for a level of expenditure. In addition, ITT A/CD is applying the MCE process to other programs to improve the company's production efficiency and further its competitive position.

Postmortem Process

Previously, ITT A/CD used an informal method to distribute information on problems found during the documentation review of the QRC & QRT process. Communication consisted of informal memos and photographs of these assembly issues. Since the information did not always reach all concerned parties, the same problems often reoccurred. In addition, no formal follow-up system existed to prevent a recurrence on subsequent designs.

The Postmortem Process starts in the QRC where documentation, process assembly, and test issues are recorded. Issues are reviewed for merit by a QRC supervisor and advanced manufacturing engineers. Following the review, issues are taken directly to the person responsible and discussed further. Next, corrective actions are undertaken, and a formal postmortem report is generated. Each report is also reviewed by manufacturing and engineering personnel in a formal meeting. Any issues that are not resolved or require a root cause elimination are generated on an action register. The Postmortem Process is an extension of the QRC & QRT process.

ITT A/CD's Postmortem Process improves the manufacturability and testability of products built in the QRC. In addition, the process identifies consistent issues, and tracks the progress in resolving problems. Information obtained from the Postmortem Process enables engineers to generate QRC Job Start Checklists and improve design guidelines.

Product Assurance Requirements Definition

Product Assurance Requirements Definition (PARD) is a process which documents supplier quality requirements as detailed by specifications, internal procedures, and the contract. PARD also works as an agreement between Quality Engineering; Procurement; Purchased Material Inspection (PMI); and Supplier Support and Development (SSD). Previously, supplier quality requirements were arbitrarily determined by Quality Engineering. This informal method had minimal documentation and poor communication between Quality Engineering and Procurement. ITT A/CD needed to eliminate its inconsistencies in assigning supplier quality requirements, and establish up-front agreements to identify these requirements.

ITT A/CD organized PARD into two sections. The first section provides inspection information such as critical parameters, sampling plan, source inspection, first piece requirements, and special test requirements. The second section identifies quality and/or manufacturing information to be conveyed to the supplier. Quality Engineering, Procurement, PMI, and SSD now work together on defining requirements, and each has specified responsibilities. Quality Engineering generates the specific project PARD; coordinates the review with the other functions; and controls the revision and distribution of PARD. Procurement, PMI, and SSD review PARD, work to resolve issues, ensure compliance to the requirements, and notify the supplier of the requirements.

PARD provides ITT A/CD with a formal process to review contract and internal requirements; identify inspection requirements; classify supplier requirements by program, commodity, or individual part; route information for review; and distribute final documentation once approved. Additional benefits include consistent application of requirements for each commodity; shorter intervals between the creation of requisitions to the release of purchase orders; and up-front agreements on requirements that are understood by all internal organizations. PARD enables ITT A/CD to be more efficient in its procurement process.

Re-engineered Test Program

Prior to NASA launching a GOES weather satellite, ITT A/CD used a test system to collect data from the GOES instruments to verify they were properly working. Data is collected from such locations as the instrument builders, the spacecraft builder, and the

launch platform. However, the current system has many problems: aging test equipment; manual analysis of data; difficult maintainability due to customized designs and outdated technology; and cumbersome test execution and analysis due to sequential operation. In addition, data is not always archived and has limited accessibility. As newer programs were started, ITT A/CD and NASA recognized the need to improve the test system. Currently, the company is in the final design and assembly stages of the Re-engineered Test Program (RTP).

ITT A/CD, in cooperation with NASA, established various goals for the RTP such as improved test cycle time; a single-point test system which covers integration at the instrument, spacecraft, and launch phases; automation of routine tasks to reduce operator error; trend capability throughout the lifetime of the product; accessible archive information for analysis and troubleshooting; easy upgradeability; and accessibility by the customer community. Key elements of the RTP include test execution system, data archive, environmental chamber, bench test, data analysis system, spacecraft ground support equipment, and test operator interfaces. To aid in the collection and analysis of data, ITT A/CD added system tools such as essential model, quality functional diagram, parameter diagrams, technical performance measurements, interface control documents, and formal document control. RTP equipment will also be very flexible with its modular design, Ethernet network, and extensive use of commercial equipment.

Once the RTP is fully operational, test time is expected to decrease from greater than 230 days to approximately 180 days. In addition, ITT A/CD estimates the new system will produce a savings of approximately $2.4 million.

Logistics

Test Equipment Integration

ITT A/CD's Logistics Division supports various programs by being involved in the redesign, test, monitoring, and control of complex projects as well as providing coordination and direction, and interacting with internal and external customers. As demonstrated by its current support activities on the SINCGARS Radio Communications Test System, the Division sustains a high level of capability to deal with all types of logistics problems.

In 1994, the Logistics Division performed a technical review on the Army's field test equipment (AN/GRM-114) used for the SINCGARS program. This review revealed numerous shortcomings and offered recommendations that were not previously addressed by the Army or the contractor. In 1995, the Division continued its support by being involved in implementing the improvement phase which led to the AN/GRM-122. The Logistics Division not only demonstrated a strong technical understanding of the SINCGARS radio and field test equipment, but facilitated the customer and the user agreement on requirements definitions, system configuration, and schedules. The Division's strength for dealing with this type of logistics support comes from its employees' expertise and years of field experience. Many employees served active duty in the military, and had operated the same field equipment which they now support.

As a result of ITT A/CD's Test Equipment Integration support for the Army's AN/GRM field test equipment, the SINCGARS program has become quite successful. The AN/GRM-122 offers a 25% cost reduction over the previous AN/GRM-114, and uses the latest plug and play concepts to allow for lower cost developments of future enhancements as well as adaptability to other radios that fall within the parameters of the unit.

Management

American Express Procurement Card Program

Prior to 1996, ITT A/CD used a standard process to handle small purchase orders. This process required 25 steps from the time the requester defined the purchase requirements to the close-out point of the purchase order. Typical turnaround times were two weeks for the requestor to receive supplies/services, and 30 to 45 days for the supplier to receive payment. At an estimated cost of $175 per transaction for small purchase orders, ITT A/CD typically completed 4,000 orders for indirect supplies/services that were less than $150, and an additional 3,030 orders on those less than $500. In mid-1996, ITT A/CD implemented the American Express Procurement Card program which simplified the procurement process, improved productivity, enhanced internal controls, increased customer satisfaction, and achieved significant savings.

The American Express Procurement Card program uses credit cards that are hard coded with complete accounting and tax information. This approach removes the possibility of errors and allows billing downloads to occur without manual intervention. The program also reduces the procurement steps to 10, and decreases the purchase order cost to $18 per

transaction. All purchases less than $500, excluding certain commodities such as chemicals and once-a-year purchases, are eligible under this program. Through the American Express Procurement Card program, ITT A/CD now completes more than 5,000 small purchase orders per year, and achieved a total annual savings of $785,000. Requesters receive indirect supplies/services in three to four days, and suppliers receive payment from American Express in three days. One monthly consolidated bill and one monthly check cover all of ITT A/CD's transactions.

Engineering Development Program

ITT A/CD implemented a formal program to train future engineers whose skills could be applied in any or all of the organization's functional areas. This effort was accomplished by placing recent engineering graduates into a two-year program of rotational assignments and formal training. Previously, each functional area was responsible for internal skills development of newly hired engineers, resulting in a tendency to train and hold on to people. Since departments competed for assets, they resisted sharing personnel and resolved skill shortages by hiring externally. In addition, cross-training occurred only during team participation.

Established in January 1998, the Engineering Development Program (EDP) helps ITT A/CD's Operations compete for high quality engineers internally and externally. The program offers added incentives for new hires to join the manufacturing organization. Provided as part of the rotational design of EDP, networking facilitates rapid development and learning, and helps the trainees quickly establish relationships that will be useful throughout their careers. The company also implemented EDP partly in response to the changing environment of DOD's program funding constraints and downsizing efforts, which tends to place greater value on generalists as opposed to specialists.

Minimum requirements for the program are a general knowledge of manufacturing techniques and a bachelor of science or equivalent, preferably in manufacturing, materials, electrical, chemical, mechanical, or industrial engineering. In addition, minimal work experience is required since the positions are entry level. However, co-op experience is desirable in a manufacturing environment encompassing metal fabrication, microelectronics, and electronic assembly and test.

Trainees spend six months in four different areas: Manufacturing Operations (e.g., equipment, floor support, union interface); Operations Engineering (e.g., engineering interface, new technology); Quality (e.g., problem solving, customer interface); and Materials/Operations Planning and Control (e.g., supplier interface). At the start of each rotation cycle, each trainee reports to a mentor and is assigned a direct charge job. The trainees must be self starters and have a great deal of initiative. Assignments provide insight into each rotation-specific operational infrastructure, and offer a challenging work environment under supervision. Work assignments are of reasonable complexity, requiring a moderate degree of improvisation in the application of procedures and methods. The trainees are given a high degree of responsibility and authority during the training program including exposure to employee relations; equipment, materials, products, and money management; and development of internal and external business contacts. Performance reviews are done at the end of each rotational cycle, providing each trainee with four complete reviews during the two-year period. The Director of Operations Engineering oversees the program's administration.

Although EDP is new, ITT A/CD is already seeing the benefit of providing a well-rounded exposure to new hires and mutually deciding where they best fit in the organization based on demonstrated results. Departments can now share personnel through networking and planned movement of employees between functional areas. Skill shortages can be filled through a combination of hiring and internal skills development. Cross training can be planned more effectively, and trainees will gain increased exposure to the entire organization. EDP's first class of trainees has four engineers. The pipeline will be filled with new candidates each year, and these trainees will eventually become mentors themselves. Future plans call for sharing the experiences with local universities, so they can familiarize potential candidates with the benefits of EDP and align the candidate selection process with the ongoing co-op program.

Manufacturing for Design Initiative

ITT A/CD's Manufacturing for Design (MFD) initiative places special emphasis on developing critical manufacturing and test technologies for current and future programs. The MFD mission requires Operations Engineering to provide proven, enabling technologies to the product development team prior to the start of detailed designing. This approach allows product designs to be done in a reliable, robust, and cost-effective manner over a shorter period of time and at the best value.

Over the years, ITT A/CD's product development model evolved from an over-the-wall approach to one focused on IPD; integrated process and product design; concurrent engineering; and colocated resources. MFD further augmented this development model by addressing new challenges set by ITT A/CD's customers. These challenges included reduced cycle time, aggressive cost reductions, and reliability improvement goals. The company's cycle time requirements (program kick-off to product delivery) have steadily decreased from three years to one year. Product cost is also being driven down by competition, and higher product reliability is a direct requirement of the customer.

The MFD initiative requires an excellent understanding of operations and design capabilities, and a knowledge of major design and manufacturing technology advances that impact equipment, facilities, and techniques for product fabrication. MFD's objectives include establishing proven advanced manufacturing technologies at the start of the program; contributing to low risk/short cycle time advanced product development; minimizing the chance of program restarts; and implementing planning, cost-effective investment, and feedback control. ITT A/CD uses the MFD initiative to understand the company's needs, direction, and vision over the next five to ten years; envision its technology maturity and direction on a global scale; and emphasize the development of a short/long term operation plan. The company's Technology Roadmap works as an integrated master plan to track the critical manufacturing and test technology needs for current and future programs relative to the MFD initiative.

All technologies pursued by Operations Engineering receive support from ITT A/CD's functional groups and are tied to the company's business initiative. In 1998, ITT A/CD increased its allocation of critical operations IR&D funding by 50%. As a result of the MFD initiative, Operations Engineering brings its manufacturing and test technologies to production at the right time and at the best value.

Operator Self Inspection Program

In 1996, ITT A/CD established the Operator Self Inspection (OSI) program to integrate the inspection step into the production process, verify instruction documentation by the end user, and strengthen build-to-print capabilities. By checking the product as it is being produced, operators can identify problem indicators early in the process, and minimize waste, redundancy, and rework. The OSI program is typically implemented into a pilot area of a production process, and run as a dual system against traditional inspections until the area is validated.

ITT A/CD maintains control of OSI through three procedural documents: OSI Certification/Audit System; OSI Procedure; and First Piece Inspection Procedure. These documents address various topics such as OSI definitions, operator certification, audits, procedural instructions, manufacturing verification, and record keeping. Operators must successfully pass audits of their work in production to become OSI certified, maintain this certification, and be re-certified if changes occur with the product or production process.

Operator ownership is the key to the OSI program. ITT A/CD's OSI operators are well trained, think proactively, function independently, require minimal supervision, and accept the responsibility and authority needed to oversee a process. By using OSI, the company reduced its in-process inspection costs by 75%, decreased cycles times, developed a quicker response to rework, eliminated inspection queues, and established a flow-down checking with Quality Control Final Inspection.

Small Business Program

Small business programs are designed to promote performance opportunities for those businesses categorized as small; small disadvantaged; and women-owned small. Any contractor that receives a government contract exceeding $500,000 and has subcontracting opportunities is required to afford these businesses with a maximum, practicable chance of participating in the contract. The level of participation is then reported to the government. ITT A/CD's previous process addressed these requirements on a contract-by-contract basis with no comprehensive view on overall performance. Although small business information was kept in a central database, users often found the data to be incomplete and outdated. In addition, the one-person Small Business Liaison Office shouldered the responsibility of finding and implementing new approaches to identify opportunities for small businesses. In response, ITT A/CD established the Small Business program which employs all facets of the corporation and receives support from top-level management.

Through its Small Business program, ITT A/CD established a standardized process to handle small business plans and review internal performance; set up a procurement team to address utilization performance; and developed a small business library to

identify small business opportunities. The company uses a small business boilerplate for all small business plans which provides an in-depth look at the program and the utilization performance. The cross-functional procurement team reviews, monitors, and enhances utilization performance from all procurement areas, and develops innovative approaches to integrate small businesses into the performance aspect of contracts. A user-friendly, easily-accessible small business library houses information on small businesses. This data is categorized by supplier name, as well as type of service and supply.

Since implementing the Small Business program, ITT A/CD increased its utilization of small businesses. Small disadvantaged and woman-owned small businesses' performances increased by 50% over the past two years (from 1.9% to 3.1%), and ITT A/CD exceeded its 25% business requirement with a 35% small business contracting performance. In addition, the company established mutually-beneficial partnerships with these businesses, and received several incentive awards from NASA based on the program's proactive development and activities.

Appendix A

Table of Acronyms

Acronym	Definition
A/CD	Aerospace/Communications Division
APD	Advanced Process Development
ATE	Automated Test Equipment
AVHRR	Advanced Very High Resolution Radiometer
BOM	Bill of Material
COTS	Commercial-Off-The-Shelf
CPMC	Common Process Management Council
DAT	Defect Analysis Team
DCMC	Defense Contract Management Command
DTC	Design-to-Cost
DTS	Dock-to-Stock
EDP	Engineering Development Program
EDR	Environmental Data Record
ESS	Environmental Stress Screening
EVMS	Earned Value Management System
FRACAS	Failure Reporting, Analysis, and Corrective Action System
FSR	Field Service Representative
GOES	Geostationary Operational Environmental Satellite
ILS	Integrated Logistics Support
IMP	Integrated Management Plan
IPD	Integrated Product Development
IPT	Integrated Product Team
IR	Incident Report
IR&D	Independent Research and Development
ITT	International Telephone and Telegraph Corporation
LAV	Light Assault Vehicle
MCE	Manufacturing Confidence Evaluation
MFD	Manufacturing for Design
MTBF	Mean Time Between Failures
NPOESS	National Polar-orbiting Operational Environmental Satellite System

Acronym	Definition
OSI	Operator Self Inspection
PAL	Product Assurance Laboratory
PARD	Product Assurance Requirements Definition
PDCD	Product Design Components Database
PLTU	Parts List Transfer Utility
PMI	Purchased Material Inspection
PPPRA	Production Process Proofing Risk Assessment
PRAT	Production Reliability Acceptance Testing
PROCAS	Process Oriented Contract Administration Services
QRC	Quick Reaction Center
QRT	Quick Reaction Test
RMA	Resin Mildly Activated
RTP	Re-engineered Test Program
SBIRS	Satellite-Based Infrared System
SINCGARS	Single Channel Ground and Airborne Radio System
SIPD	Supplier Integrated Product Development
SMD-PD	Surface Mount Device Processing Database
SSD	Supplier Support and Development
TAAF	Test, Analyze, and Fix
TDI	Top Drawing Index

Appendix B

BMP Survey Team

Team Member	Activity	Function
Larry Robertson (812) 854-5336	**Crane Division** **Naval Surface Warfare Center** Crane, IN	**Team Chairman**
Cheri Spencer (301) 403-8100	**BMP Center of Excellence** College Park, MD	**Technical Writer**

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Dick Beasley (812) 854-5982	**Naval Surface Warfare Center** Crane, IN	
Tom Davidson (812) 854-2381	**Naval Surface Warfare Center** Crane, IN	

Production & Facilities Team

Nick Keller (812) 854-5331	**Naval Surface Warfare Center** Crane, IN	**Team Leader**
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Richard Goodwin (909) 273-5472	**Naval Warfare Assessment Division** Corona, CA	

Management & Logistics Team

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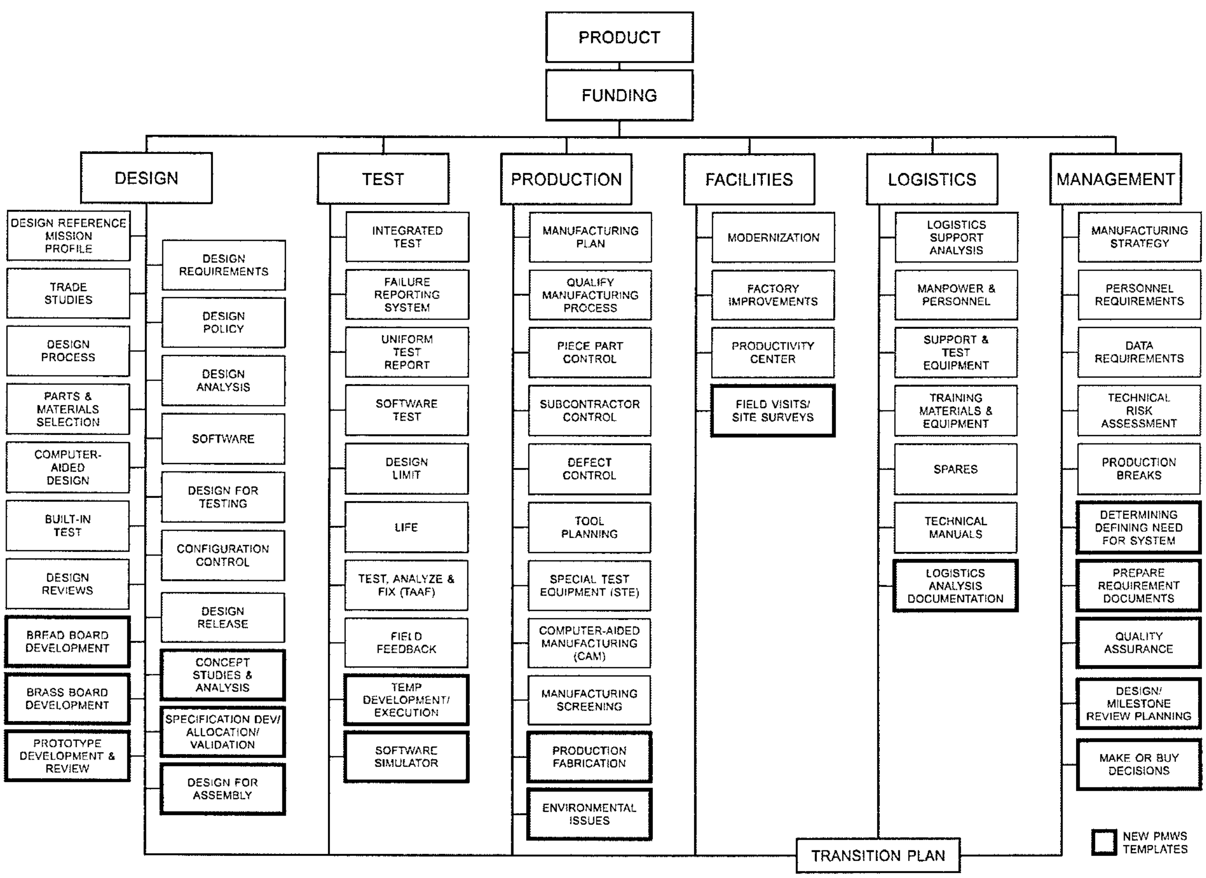
Larry Halbig (317) 306-3838	**Raytheon Systems Company** Indianapolis, IN	

Appendix C
Critical Path Templates and BMP Templates

This survey was structured around and concentrated on the functional areas of design, test, production, facilities, logistics, and management as presented in the Department of Defense 4245.7-M, *Transition from Development to Production* document. This publication defines the proper tools—or templates—that constitute the critical path for a successful material acquisition program. It describes techniques for improving the acquisition process by addressing it as an *industrial* process that focuses on the product's design, test, and production phases which are interrelated and interdependent disciplines.

The BMP program has continued to build on this knowledge base by developing 17 new templates that complement the existing DOD 4245.7-M templates. These BMP templates address new or emerging technologies and processes.

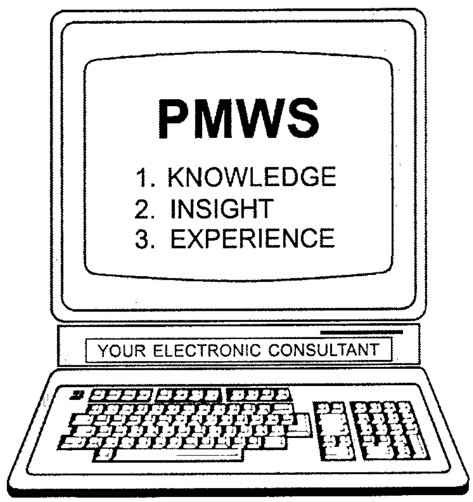
"CRITICAL PATH TEMPLATES FOR TRANSITION FROM DEVELOPMENT TO PRODUCTION"



Appendix D

BMPnet and the Program Manager's WorkStation

The BMPnet, located at the Best Manufacturing Practices Center of Excellence (BMPCOE) in College Park, Maryland, supports several communication features. These features include the Program Manager's WorkStation (**PMWS**), electronic mail and file transfer capabilities, as well as access to Special Interest Groups (SIGs) for specific topic information and communication. The BMPnet can be accessed through the World Wide Web (at http://www.bmpcoe.org), through free software that connects directly over the Internet or through a modem. The PMWS software is also available on CD-ROM.



PMWS provides users with timely acquisition and engineering information through a series of interrelated software environments and knowledge-based packages. The main components of PMWS are KnowHow, SpecRite, the Technical Risk Identification and Mitigation System (TRIMS), and the BMP Database.

KnowHow is an intelligent, automated program that provides rapid access to information through an intelligent search capability. Information currently available in KnowHow handbooks includes Acquisition Streamlining, Non-Development Items, Value Engineering, NAVSO P-6071 (Best Practices Manual), MIL-STD-2167/2168 and the DoD 5000 series documents. KnowHow cuts document search time by 95%, providing critical, user-specific information in under three minutes.

SpecRite is a performance specification generator based on expert knowledge from all uniformed services. This program guides acquisition personnel in creating specifications for their requirements, and is structured for the build/approval process. SpecRite's knowledge-based guidance and assistance structure is modular, flexible, and provides output in MIL-STD 961D format in the form of editable WordPerfect® files.

TRIMS, based on DoD 4245.7-M (the transition templates), NAVSO P-6071, and DoD 5000 event-oriented acquisition, helps the user identify and rank a program's high-risk areas. By helping the user conduct a full range of risk assessments throughout the acquisition process, TRIMS highlights areas where corrective action can be initiated before risks develop into problems. It also helps users track key project documentation from concept through production including goals, responsible personnel, and next action dates for future activities.

The **BMP Database** contains proven best practices from industry, government, and the academic communities. These best practices are in the areas of design, test, production, facilities, management, and logistics. Each practice has been observed, verified, and documented by a team of government experts during BMP surveys.

Access to the BMPnet through dial-in or on Internet requires a special modem program. This program can be obtained by calling the BMPnet Help Desk at (301) 403-8179 or it can be downloaded from the World Wide Web at http://www.bmpcoe.org. To receive a user/e-mail account on the BMPnet, send a request to helpdesk@bmpcoe.org.

Appendix E
Best Manufacturing Practices Satellite Centers

There are currently nine Best Manufacturing Practices (BMP) satellite centers that provide representation for and awareness of the BMP program to regional industry, government and academic institutions. The centers also promote the use of BMP with regional Manufacturing Technology Centers. Regional manufacturers can take advantage of the BMP satellite centers to help resolve problems, as the centers host informative, one-day regional workshops that focus on specific technical issues.

Center representatives also conduct BMP lectures at regional colleges and universities; maintain lists of experts who are potential survey team members; provide team member training; identify regional experts for inclusion in the BMPnet SIG e-mail; and train regional personnel in the use of BMP resources such as the BMPnet.

The nine BMP satellite centers include:

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Appendix F
Navy Manufacturing Technology Centers of Excellence

The Navy Manufacturing Sciences and Technology Program established the following Centers of Excellence (COEs) to provide focal points for the development and technology transfer of new manufacturing processes and equipment in a cooperative environment with industry, academia, and Navy centers and laboratories. These COEs are consortium-structured for industry, academia, and government involvement in developing and implementing technologies. Each COE has a designated point of contact listed below with the individual COE information.

Best Manufacturing Practices Center of Excellence

The Best Manufacturing Practices Center of Excellence (BMPCOE) provides a national resource to identify and promote exemplary manufacturing and business practices and to disseminate this information to the U.S. Industrial Base. The BMPCOE was established by the Navy's BMP program, Department of Commerce's National Institute of Standards and Technology, and the University of Maryland at College Park, Maryland. The BMPCOE improves the use of existing technology, promotes the introduction of improved technologies, and provides non-competitive means to address common problems, and has become a significant factor in countering foreign competition.

Point of Contact:
Mr. Ernie Renner
Best Manufacturing Practices Center of Excellence
4321 Hartwick Road
Suite 400
College Park, MD 20740
(301) 403-8100
FAX: (301) 403-8180
ernie@bmpcoe.org

Center of Excellence for Composites Manufacturing Technology

The Center of Excellence for Composites Manufacturing Technology (CECMT) provides a national resource for the development and dissemination of composites manufacturing technology to defense contractors and subcontractors. The CECMT is managed by the Great Lakes Composites Consortium and represents a collaborative effort among industry, academia, and government to develop, evaluate, demonstrate, and test composites manufacturing technologies. The technical work is problem-driven to reflect current and future Navy needs in the composites industrial community.

Point of Contact:
Dr. Roger Fountain
Center of Excellence for Composites Manufacturing Technology
c/o GLCC, Inc.
103 Trade Zone Drive
Suite 26C
West Columbia, SC 29170
(803) 822-3705
FAX: (803) 822-3730
rfglcc@glcc.org

Electronics Manufacturing Productivity Facility

The Electronics Manufacturing Productivity Facility (EMPF) identifies, develops, and transfers innovative electronics manufacturing processes to domestic firms in support of the manufacture of affordable military systems. The EMPF operates as a consortium comprised of industry, university, and government participants, led by the American Competitiveness Institute under a CRADA with the Navy.

Point of Contact:
Mr. Alan Criswell
Electronics Manufacturing Productivity Facility
One International Plaza
Suite 600
Philadelphia, PA 19113
(610) 362-1200
FAX: (610) 362-1290
criswell@aci-corp.org

National Center for Excellence in Metalworking Technology

The National Center for Excellence in Metalworking Technology (NCEMT) provides a national center for the development, dissemination, and implementation of advanced technologies for metalworking products and processes. The NCEMT, operated by Concurrent Technologies Corporation, helps the

Navy and defense contractors improve manufacturing productivity and part reliability through development, deployment, training, and education for advanced metalworking technologies.

Point of Contact:
Mr. Richard Henry
National Center for Excellence in Metalworking Technology
c/o Concurrent Technologies Corporation
100 CTC Drive
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(814) 269-2532
FAX: (814) 269-2501
henry@ctc.com

Navy Joining Center

The Navy Joining Center (NJC) is operated by the Edison Welding Institute and provides a national resource for the development of materials joining expertise and the deployment of emerging manufacturing technologies to Navy contractors, subcontractors, and other activities. The NJC works with the Navy to determine and evaluate joining technology requirements and conduct technology development and deployment projects to address these issues.

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Energetics Manufacturing Technology Center

The Energetics Manufacturing Technology Center (EMTC) addresses unique manufacturing processes and problems of the energetics industrial base to ensure the availability of affordable, quality, and safe energetics. The focus of the EMTC is on process technology with a goal of reducing manufacturing costs while improving product quality and reliability. The EMTC also maintains a goal of development and implementation of environmentally benign energetics manufacturing processes.

Point of Contact:
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Energetics Manufacturing Technology Center
Indian Head Division
Naval Surface Warfare Center
101 Strauss Avenue
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Indian Head, MD 20640-5035
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mt@command.ih.navy.mil

Institute for Manufacturing and Sustainment Technologies

The Institute for Manufacturing and Sustainment Technologies (iMAST), was formerly known as Manufacturing Science and Advanced Materials Processing Institute. Located at the Pennsylvania State University's Applied Research Labortory, the primary objective of iMAST is to address challenges relative to Navy and Marine Corps weapon system platforms in the areas of mechnical drive transmission techologies, materials science technologies, high energy processing technologies, and repair technology.

Point of Contact:
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Institute for Manufacturing and Sustainment Technologies
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National Network for Electro-Optics Manufacturing Technology

The National Netowork for Electro-Optics Manufacturing Technology (NNEOMT), a low overhead virtual organization, is a national consortium of electro-optics industrial companies, universities, and government research centers that share their electro-optics expertise and capabilities through project teams focused on Navy requirements. NNEOMT is managed by the Ben Franklin Technology Center of Western Pennsylvania.

Point of Contact:
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National Network for Electro-Optics Manufacturing Technology
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Gulf Coast Region Maritime Technology Center

The Gulf Coast Region Maritime Technology Center (GCRMTC) is located at the University of New Orleans and focuses primarily on product developments in support of the U.S. shipbuilding industry. A sister site at Lamar University in Orange, Texas focuses on process improvements.

Point of Contact:
Dr. John Crisp, P.E.
Gulf Coast Region Maritime Technology Center
University of New Orleans
College of Engineering
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Manufacturing Technology Transfer Center

The focus of the Manufacturing Technology Transfer Center (MTTC) is to implement and integrate defense and commercial technologies and develop a technical assistance network to support the Dual Use Applications Program. MTTC is operated by Innovative Productivity, Inc., in partnership with industry, government, and academia.

Point of Contact:
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Manufacturing Technology Transfer Center
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Appendix G
Completed Surveys

As of this publication, 108 surveys have been conducted and published by BMP at the companies listed below. Copies of older survey reports may be obtained through DTIC or by accessing the BMPnet. Requests for copies of recent survey reports or inquiries regarding the BMPnet may be directed to:

Best Manufacturing Practices Program
4321 Hartwick Rd., Suite 400
College Park, MD 20740
Attn: Mr. Ernie Renner, Director
Telephone: 1-800-789-4267
FAX: (301) 403-8180
ernie@bmpcoe.org

1985	Litton Guidance & Control Systems Division - Woodland Hills, CA
1986	Honeywell, Incorporated Undersea Systems Division - Hopkins, MN (Alliant TechSystems, Inc.) Texas Instruments Defense Systems & Electronics Group - Lewisville, TX General Dynamics Pomona Division - Pomona, CA Harris Corporation Government Support Systems Division - Syosset, NY IBM Corporation Federal Systems Division - Owego, NY Control Data Corporation Government Systems Division - Minneapolis, MN
1987	Hughes Aircraft Company Radar Systems Group - Los Angeles, CA ITT Avionics Division - Clifton, NJ Rockwell International Corporation Collins Defense Communications - Cedar Rapids, IA UNISYS Computer Systems Division - St. Paul, MN (Paramax)
1988	Motorola Government Electronics Group - Scottsdale, AZ General Dynamics Fort Worth Division - Fort Worth, TX Texas Instruments Defense Systems & Electronics Group - Dallas, TX Hughes Aircraft Company Missile Systems Group - Tucson, AZ Bell Helicopter Textron, Inc. - Fort Worth, TX Litton Data Systems Division - Van Nuys, CA GTE C^3 Systems Sector - Needham Heights, MA
1989	McDonnell-Douglas Corporation McDonnell Aircraft Company - St. Louis, MO Northrop Corporation Aircraft Division - Hawthorne, CA Litton Applied Technology Division - San Jose, CA Litton Amecom Division - College Park, MD Standard Industries - LaMirada, CA Engineered Circuit Research, Incorporated - Milpitas, CA Teledyne Industries Incorporated Electronics Division - Newbury Park, CA Lockheed Aeronautical Systems Company - Marietta, GA Lockheed Corporation Missile Systems Division - Sunnyvale, CA Westinghouse Electronic Systems Group - Baltimore, MD General Electric Naval & Drive Turbine Systems - Fitchburg, MA Rockwell International Corporation Autonetics Electronics Systems - Anaheim, CA TRICOR Systems, Incorporated - Elgin, IL
1990	Hughes Aircraft Company Ground Systems Group - Fullerton, CA TRW Military Electronics and Avionics Division - San Diego, CA MechTronics of Arizona, Inc. - Phoenix, AZ Boeing Aerospace & Electronics - Corinth, TX Technology Matrix Consortium - Traverse City, MI Textron Lycoming - Stratford, CT

1991	*Resurvey of Litton Guidance & Control Systems Division* - Woodland Hills, CA Norden Systems, Inc. - Norwalk, CT Naval Avionics Center - Indianapolis, IN United Electric Controls - Watertown, MA Kurt Manufacturing Co. - Minneapolis, MN MagneTek Defense Systems - Anaheim, CA Raytheon Missile Systems Division - Andover, MA AT&T Federal Systems Advanced Technologies and AT&T Bell Laboratories - Greensboro, NC and Whippany, NJ *Resurvey of Texas Instruments Defense Systems & Electronics Group* - Lewisville, TX
1992	Tandem Computers - Cupertino, CA Charleston Naval Shipyard - Charleston, SC Conax Florida Corporation - St. Petersburg, FL Texas Instruments Semiconductor Group Military Products - Midland, TX Hewlett-Packard Palo Alto Fabrication Center - Palo Alto, CA Watervliet U.S. Army Arsenal - Watervliet, NY Digital Equipment Company Enclosures Business - Westfield, MA and Maynard, MA Computing Devices International - Minneapolis, MN *(Resurvey of Control Data Corporation Government Systems Division)* Naval Aviation Depot Naval Air Station - Pensacola, FL
1993	NASA Marshall Space Flight Center - Huntsville, AL Naval Aviation Depot Naval Air Station - Jacksonville, FL Department of Energy Oak Ridge Facilities (Operated by Martin Marietta Energy Systems, Inc.) - Oak Ridge, TN McDonnell Douglas Aerospace - Huntington Beach, CA Crane Division Naval Surface Warfare Center - Crane, IN and Louisville, KY Philadelphia Naval Shipyard - Philadelphia, PA R. J. Reynolds Tobacco Company - Winston-Salem, NC Crystal Gateway Marriott Hotel - Arlington, VA Hamilton Standard Electronic Manufacturing Facility - Farmington, CT Alpha Industries, Inc. - Methuen, MA
1994	Harris Semiconductor - Melbourne, FL United Defense, L.P. Ground Systems Division - San Jose, CA Naval Undersea Warfare Center Division Keyport - Keyport, WA Mason & Hanger - Silas Mason Co., Inc. - Middletown, IA Kaiser Electronics - San Jose, CA U.S. Army Combat Systems Test Activity - Aberdeen, MD Stafford County Public Schools - Stafford County, VA
1995	Sandia National Laboratories - Albuquerque, NM Rockwell Defense Electronics Collins Avionics & Communications Division - Cedar Rapids, IA *(Resurvey of Rockwell International Corporation Collins Defense Communications)* Lockheed Martin Electronics & Missiles - Orlando, FL McDonnell Douglas Aerospace (St. Louis) - St. Louis, MO *(Resurvey of McDonnell-Douglas Corporation McDonnell Aircraft Company)* Dayton Parts, Inc. - Harrisburg, PA Wainwright Industries - St. Peters, MO Lockheed Martin Tactical Aircraft Systems - Fort Worth, TX *(Resurvey of General Dynamics Fort Worth Division)* Lockheed Martin Government Electronic Systems - Moorestown, NJ Sacramento Manufacturing and Services Division - Sacramento, CA JLG Industries, Inc. - McConnellsburg, PA
1996	City of Chattanooga - Chattanooga, TN Mason & Hanger Corporation - Pantex Plant - Amarillo, TX Nascote Industries, Inc. - Nashville, IL Weirton Steel Corporation - Weirton, WV NASA Kennedy Space Center - Cape Canaveral, FL Department of Energy, Oak Ridge Operations - Oak Ridge, TN

1997	Headquarters, U.S. Army Industrial Operations Command - Rock Island, IL SAE International and Performance Review Institute - Warrendale, PA Polaroid Corporation - Waltham, MA Cincinnati Milacron, Inc. - Cincinnati, OH Lawrence Livermore National Laboratory - Livermore, CA Sharretts Plating Company, Inc. - Emigsville, PA Thermacore, Inc. - Lancaster, PA Rock Island Arsenal - Rock Island, IL Northrop Grumman Corporation - El Segundo, CA *(Resurvey of Northrop Corporation Aircraft Division)* Letterkenny Army Depot - Chambersburg, PA Elizabethtown College - Elizabethtown, PA Tooele Army Depot - Tooele, UT
1998	United Electric Controls - Watertown, MA Strite Industries Limited - Cambridge, Ontario, Canada Northrop Grumman Corporation - El Segundo, CA Corpus Christi Army Depot - Corpus Christi, TX Anniston Army Depot - Anniston, AL Naval Air Warfare Center, Lakehurst - Lakehurst, NJ Sierra Army Depot - Herlong, CA ITT Industries Aerospace/Communications Division - Fort Wayne, IN